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**MSc Exercise & Nutrition Science**

# DO GRADUATED COMPRESSION GARMENTS IMPROVE FIELD-HOCKEY SKILL PERFORMANCE AND REPEATED SPRINT ABILITY FOLLOWING AN INTERMITTENT ENDURANCE TEST?

**Jonathan Heath**

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# ABSTRACT

**Do graduated compression garments improve field-hockey skill performance and repeated sprint ability following an intermittent endurance test?**

**Jonathan Heath**

**Introduction:** Compression garments have long been shown to promote physiological benefits both within the medical profession and also within the sporting arena. Team sports such as field-hockey, football and rugby are characterised by high intensity intermittent exercise, also requiring a significant contribution of motor skill performance and cognitive function. To date there is paucity in the research regarding graduated compression garments and their effects on field-hockey skill performance.

**Method:** 14 male field-hockey players (24 ± 4 years), National League North standard, attended on five separate occasions: two familiarisation sessions and three test sessions. During testing sessions participants wore one of three clothing combinations, Control (polo shirt and shorts), Placebo and Graduated compression garments (Skins™). Placebo and Graduated compression garments were worn underneath the control clothing condition and consisted of a long sleeve top, shorts and socks. The order in which clothing conditions were tested was randomized. Testing consisted of 15 minutes rest followed by a 15 minute warm up. Participants then performed a field-hockey skill test, a repeated sprint ability test and an intermittent endurance test. Following the intermittent endurance test the field-hockey skill test and sprint test were repeated. Followed by 20 minutes recovery. Heart rates were monitored constantly throughout the test. Blood lactate, core temperature and subjective whole thermal ratings, clothing sweating sensation, clothing comfort sensations and Ratings of Perceived Exertion (RPE), were monitored after each test component.

**Results:** Field-hockey skill results were not significantly different between clothing conditions ($p = 0.800$ and $p = 0.822$ for pre and post intermittent endurance respectively). Repeated sprint ability fatigue times showed no significant difference between clothing conditions pre intermittent endurance test ($p = 0.607$). Post intermittent endurance fatigue time was significantly different between control and placebo ($p = 0.005$), but not significant between control and graduated compression garments and between placebo and graduated compression garments ($p = 0.073$ and $p = 0.753$ respectively). Intermittent endurance results were significant ($p = 0.002$) between control and graduated compression garments (1699.92 ± 120.19m and 1767.71 ± 140.45m respectively), and between placebo and graduated compression garments (1682 ± 155.48m and 1767.71 ± 140.45m respectively). Heart rate, blood lactate and core temperature between clothing conditions were not significant ($p = 0.510$; $p = 0.893$; $p = 0.502$ respectively). Subjective whole thermal sensations were not significant ($p = 0.784$). Clothing sweating sensations were significant for graduated compression garments at field-hockey skill test post intermittent endurance ($p = 0.015$) compared to control, sprint test post intermittent endurance ($p = 0.001$) compared to control, and also during recovery ($p = 0.0014$) compared to placebo. Clothing comfort sensations were significantly improved for graduated compression garments ($p = 0.012$). RPE scores were not significant ($p = 0.444$).

**Conclusion:** Graduated compression garments do not improve field-hockey skill performance and repeated sprint ability either before or after an intermittent endurance test. They do however significantly improve intermittent endurance running, and may help to maintain skill and sprint performance at levels comparable to clothing conditions performing significantly less in an intermittent endurance test. Graduated compression garments also have significant effects on subjective clothing sweating sensations and also clothing comfort sensations.

**Key words:** Graduated compression garments, field-hockey skill, repeated sprint ability, intermittent endurance.

# DECLARATION

This work is original and has not been previously submitted in support of a Degree, qualification or other course.

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# CHAPTER 1

# INTRODUCTION

## 1. Introduction

Winning and losing in sport is separated by the smallest of margins. Elite athletes need to perform consistently at the highest level for their livelihoods. During training and competition it is a common observation that both physical and mental performance diminish during the latter stages of performance. Decreases in performance can vary across sports but the common limiting factors on performance are generally decreased muscular power and endurance, decreased motor skill performance, and mental lapses (Welsh, Davis, Burke & Williams, 2002). On this basis athletes will seek any advantage when training and competing (Gill, Beaven & Cook, 2006).

An area of technical development which has become more popular in the sporting domain during the last couple of years is the use of compression garments (Doan et al, 2003; Higgins, 2004). More often than not compression garments are worn as more of a fashion accessory (Bringard, Perry & Bulleye, 2006), but there is an ever increasing body of evidence supporting the use of compression garments for performance enhancement. Style, reduced chaffing, injury prevention, anecdotal and research-supported evidence are all documented reasons for an athlete to choose compression garments (Doan et al, 2003) in order to maximise performance.

Medical research into the use of compression hosiery and compression garments has shown significant benefits in blood circulation and lactate removal (van Geest, Veraart, Nelemans, & Neumann, 2000; Weiss & Duffy, 1999; Fletcher, Cullum, & Sheldon, 1997; Kmietowicz 1997; Godin, Rice, & Kerstein, 1987; Cornwall, Doré, & Lewis, 1987; Lambert & Chow, 2004;

Hirai, Iwata, & Hayakawa, 2002; Jonker, de Boer, Ader, & Bezemer, 2001; Agu, Baker & Seifalian, 2004). On this basis sports physiologists (Higgins, Naughton & Burgess, 2007; Bringard, Perrey, & Belluye, 2006; Kraemer, Bush, & Newton, 1997; Fusco & Bohm, 2002; Agu, Baker & Seifalian, 2004; Higgins, 2004; Lambert, 2005a; Doan et al, 2003; Shim et al, 2001) suggest that the use of compression garments during sports performance will have a fatigue delaying effect. Quite often modern training clothing is worn simply as a fashion garment (Bringard, Perrey, & Belluye, 2006). Recently the use of compression garments in sporting activities has become more popular (Bringard, Perrey & Belluye, 2006; Doan et al, 2003; Kraemer, Bush & Newton, 1997) as the need to minimise the stress of exercise and improve physical fitness has dramatically increased.

To date, research into the effects of compression clothing on performance has mainly been evaluated during power sports, e.g. sprinting and weight lifting (Bringard, Perrey & Belluye, 2006). Team sports such as field-hockey, football and rugby, which are characterised by intermittent high intensity exercise, also require a significant contribution of motor skill performance and cognitive function (Burke, 1997; Sunderland & Nevill, 2005). There are few studies that have studied the effects of fatiguing exercise on motor skill performance and cognitive function (Sunderland & Nevill, 2005; Dawson, Elliot, Pyke, & Rogers, 1985; McGregor, Nicholas, Lakomy, & Williams, 1999; Rico-Sanz et al, 1996; Vergauwen, Brouns, & Hespel, 1998). One study that has tested the effects of fatiguing exercise on field hockey skill performance found that skill performance was significantly reduced (Sunderland & Nevill, 2005). In particular, there is a lack of research on the effects of wearing compression garments on skill performance. A pilot study on compression garments by Higgins (2004) identified that future research should be directed towards field studies in game time, focussing on blood lactate analysis, work levels, recovery times, and effects on skill performance during competition. A more recent pilot study by Pearce, Kidgell, Grikepelis and Carlson (2008) found compression garments to significantly improve motor control during a visual elbow flexion/extension task following exercise. They suggest further research is needed to clarify these primary findings.

## 2. Rationale

To date there is research that supports the use of compression for increasing propriocetion during body movement (Bringard, Perry & Belluye, 2006; Doan et al, 2003; Fusco & Bohm, 2002; Kraemer, Bush & Newton, 1997; Barrack et al, 1983; Kuster et al, 1999; Perlau, Frank & Fick, 1995). From these findings it is suggested that compression garments may benefit skill production. However, proprioception is just one aspect which contributes to skill performance. The sporting research is speculative on the benefits of compression garments in promoting proprioception. To date there is paucity in the research regarding graduated compression garments and their effects on field hockey skill performance.

There is little research supporting the use of compression garments in team based sports such as field hockey, football and rugby. These team sports are characterised by intermittent high intensity exercise, requiring a significant contribution of motor skill performance and cognitive function (Burke, 1997; Suderland & Nevill, 2005). The vast majority of research is on power events or continuous steady state exercise.

This study will use a field based testing procedure as there has only been a small number of studies carrying out field testing of graduated compression garments, possibly due to the difficulty in undertaking field testing caused by environmental conditions (Sunderland & Nevill, 2005; Higgins 2004). It is considered that a field based test will provide more representative results as it will take place on an astro-turf surface, as this is what the participants perform on, and not a laboratory treadmill test (Gore, 2000, p.286). A field based study will also expose the graduated compression garments to the environment in which they will usually be used.

Graduated compression garments (Skins™) claim to have wicking properties which promote heat loss, thus preventing over heating and any associated reduction in performance (www.skins.com.au). Research by Gavin et al (2001) found clothing claiming to have wicking properties, to have no thermoregulatory benefits under relatively hot environmental condition. Therefore there is a need to test the effects of such garments in relatively moderate to low environmental conditions, to see whether manufacturer claims are substantiated.

## 3. Aims

This study aims to look at the effectiveness of wearing graduated compression garments (socks, shorts and long sleeve shirt) on field-hockey skill performance, repeated sprint ability and intermittent endurance.

The aim of the study will be to test the following null hypotheses.

Rationale 1: Compression has been shown to increase proprioception (Perlau, Frank & Fick, 1995). On this basis it is speculated by manufacturers (Skins™, Canterbury) that compression garments may improve skill performance.

Null Hypothesis 1: "Graduated compression garments do not significantly improve field-hockey skill performance following an intermittent endurance test".

Rationale 2: It has been shown that compression garments improve power output, and also reduce fatigue. Trends of improved repeated sprint ability with compression garments were identified by Argus (2005) and Higgins (2004). However significance was not met in the case of Higgins (2004), possible due to the small sample size.

Null Hypothesis 2: "Graduated compression garments do not significantly improve repeated sprint ability following an intermittent endurance test".

Rationale 3: Studies testing the endurance benefits of compression garments are commonly done using incremental protocols using treadmills (Bringard, Perry & Bulluye, 2006; Lambert, 2005a). There is a lack of research regarding the effects of compression garments on intermittent endurance during field based protocols.

Null Hypothesis 3: "Graduated compression garments do not significantly improve intermittent endurance running".

Rationale 4: A pilot study by Higgins (2004) found compression garments to reduce heart rate by 5 to 7% during repeated sprints, although significance was not met. Other researchers (Bringard, Perry & Bulluye, 2006; Duffield & Portus, 2007; Houghton, Dawson & Maloney, 2007; Berry, Bailey, Simpkins & TeWinkle, 1990) suggest no differences in heart rates between wearing and not wearing compression garments. As there is a slight discrepancy in the research this study will test the effects of graduated compression garments on heart rate.

Null Hypothesis 4: "Graduated compression garments do not significantly reduce heart rates during exercise performance or recovery".

Rationale 5: Bringard, Perry and Bulluye (2006) and Higgins (2004) have both suggested reductions in blood lactate levels associated with wearing compression garments. However these are claims which have been inferred using other data gathered during the studies. Therefore this study will directly measure blood lactate concentrations, to either substantiate or refute these inferences.

Null Hypothesis 5: "Graduated compression garments do not significantly reduce blood lactate concentrations during exercise and recovery".

Rationale 6: Gavin et al (2001) found clothing claiming to promote evaporation (wicking properties) to provide no thermoregulatory, physiological, or comfort advantage over a cotton ensemble during or after exercise. This study was performed under relatively high environmental temperatures. The present study aims to test graduated compression garments during moderate to low environmental temperatures.

Null Hypothesis 6: "Graduated compression garments do not provide significant thermoregulatory or comfort advantages during exercise and recovery".

Rationale 7: Borgs RPE scale is considered a subjective measure of work rate and exertion level (Desgorces, Sénégas, Garcia, Decker & Noirez, 2007). This may highlight any changes in efforts between tests.

Null Hypothesis 7: "Graduated compression garments do not significantly influence ratings of perceived exertion during exercise and recovery".

## 4. Review of Literature.

### 4.1. Application of compression garments.

Compression stockings have long been recognised as being physiologically significant in the medical profession to aid the promotion of venous return from the lower extremities of the body (van Geest et al, 2000; Weiss & Duffy, 1999; Fletcher, Cullum, & Sheldon, 1997; Kmietowicz 1997; Godin, Rice, & Kerstein, 1987; Cornwall, Doré, & Lewis, 1987; Lambert & Chow, 2004). Compression therapy as a treatment for venous disorders can be traced back to the ancient Egyptians (Cornwall, Doré, & Lewis, 1987). Elastic stockings for medical purposes were first developed in the late 19$^{th}$ century (Angle & Bergan, 1997; Cornwall, Doré, & Lewis, 1987), although early models were not entirely successful as they provided uniform compression and even reverse compression (Johnson, 1985, cited in Angle & Bergan, 1997). The study by Godin, Rice, and Kerstein (1987) using non-graduated compression stockings resulted in reduced venous return in 43% of women tested with no venous disease risk factors. This figure increased to 61% in women with evidence of venous disease.

Graded compression stockings were developed in the late 1940's and are now considered superior to the early uniform compression stockings (Angle & Bergan, 1997). Graded compression garments work by the compression being stronger closest to the periphery of the body and becoming less strong as it gets towards the body's core. Creating a pressure gradient from periphery to core aids the body's natural flow of blood back to the heart in order for recirculation. Compression is an established non operative treatment of chronic venous insufficiency, although its mechanisms of action are still unclear (Agu, Baker, & Seifalian, 2004). A reduced venous return or chronic venous insufficiency in a patient is often highlighted by an oedema, although swelling of the lower legs is a common occurrence in many people (Hirai, Iwata, & Hayakawa, 2002; Jonker et al, 2001). An oedema is the pooling of blood or a build up of interstitial fluid in soft tissue. These fluids are dependant on gravity and result from a period of enforced immobility e.g. a bed bound patient in hospital. Lower leg compression stockings have been shown to significantly reduce the development of oedema in patients with varicose veins, but also in normal controls (Hirai, Iwata, & Hayakawa, 2002; Jonker et al, 2001).

A study by Agu, Baker and Seifalian (2004) suggest that compression stockings not only reducing venous pooling in subjects suffering from chronic venous insufficiency, but also increase deep tissue oxygenation. Participants (n = 10, age 56 ± 5 years) were tested at rest in supine position, standing, standing with tiptoe exercises, and walking for 5 minutes at 1.6

km/h. Deoxyhemoglobin (haemoglobin without oxygen) content within the muscle was significantly reduced under all test conditions by wearing high compression stockings (standing $p = 0.005$, tip toe exercise $p = 0.04$ and walking $p < 0.001$). Limb oxygenation, as measured by oxyhemoglobin, was significantly improved ($p = 0.03$) during walking exercise by wearing high compression stockings.

Van Geest et al (2000) found compression stockings to significantly improve ($p < 0.01$) capillary filtration rates compared to not wearing compression stockings. 12 men and 13 women (mean age 66 years) with chronic venous insufficiency were tested wearing three different compression stockings. The mean capillary filtration rate without stockings was 4.65 ± 1.68 $ml{\cdot}min^{-1}$. Mean capillary filtration rates for the three compression stockings were 3.54 ± 1.22 $ml{\cdot}min^{-1}$, 3.15 ± 1.17 $ml{\cdot}min^{-1}$ and 3.02 ± 1.12 $ml{\cdot}min^{-1}$, all significantly different to not wearing compression stockings ($p < 0.01$). This study suggests compression garments may significantly reduce the development of oedema in patients with chronic venous insufficiency.

Weiss and Duffy (1999) report that medical grade compression garments (high compression) have been shown to be beneficial against venous hypertension or congestion. They wanted to test the effects ready to wear gradient compression stockings had on venous symptoms. 19 flight attendants wore no compression stockings for two weeks, followed by a four week period of wearing light compression gradient compression stockings. Results showed the stocking to significantly improve symptoms of discomfort ($p < 0.01$), fatigue ($p < 0.05$) and aching ($p < 0.01$). However, these symptoms were assessed using visual analogue scales, therefore the results are not very objective.

On the bases of medical research into compression stockings it was hypothesised that compression garments could possibly provide performance benefits in a sporting context.

### 4.2. Sporting application of compression garments.

The first exercise related research into gradient compression garments was carried out by Berry and McMurray (1987). This study comprised of two tests. The first tested 12 males for maximal oxygen consumption ( $\dot{V}O_2max$) during a treadmill test with and without wearing graduated compression garments. Results showed no significant improvement in performance as measured by $\dot{V}O_2max$ or recovery oxygen consumption ( $\dot{V}O_2$) whilst wearing compression stockings ($p > 0.05$). The second test consisted of six males performing three separate three minute cycle ergometer tests at 110% of their $\dot{V}O_2max$. Participants wore either graduated compression garments during test and recovery, graduated compression garments during test but not recovery, or no compression garments during test and recovery. Both tests showed reductions in blood lactate whilst wearing graduated compression garments, with reductions being significant in the second test for compression during test and recovery ($p < 0.05$). However, these reductions in blood lactate were attributed to an inverse gradient created by the graduated compression stockings retaining the lactate in the muscular bed.

Maitland and Vandertuin (2002) tested three high compression garments on 15 participants from a variety of sports during isokinetic elbow and knee flexion/extension. No significant difference in muscular performance was evident in 7 of 8 tests (with p-values ranging from 0.2 to 0.9). Left elbow extension was significantly reduced whilst wearing compression garments ($p = 0.03$).

Research by Kraemeret al, (1998b) tested compression shorts on 10 males and 10 females during isokinetic knee flexion/extension and squatting. They found that although compression garments were not detrimental to performance, they did not offer any benefits either. Therefore supporting the views of Maitland and Vandertuin (2002) that compression garments are a personal choice rather than a physiological advantage.

Although there are a few studies which have shown negative effects of wearing compression garments and also graduated compression garments (Maitland & Vandertuin, 2002; Berry & McMurray, 1987; Kraemer et al, 1998b), the vast majority of research supports the use of graded compression garments in providing a number of performance benefits.

### 4.2.1. Fatigue

Compression garments have been suggested to have a fatigue reducing effect by assisting the body's action of blood flow around the body (Bringard, Perrey, & Belluye, 2006; Kraemer, Bush, & Newton, 1997). Bringard, Perry and Bulleye (2006) suggest that the increased blood circulation whilst wearing compression garments in their study was one of the reasons for a reduced energy cost/expenditure during exercise and a reduction in $\dot{V}O_2$ slow component. The $\dot{V}O_2$ slow component is the delayed rise in oxygen uptake ($\dot{V}O_2$) experienced during submaximal heavy constant running, occurring 2-3 minutes after the onset of exercise and causes oxygen uptake to rise above the expected energy requirement (Bringard, Perry & Bulleye, 2006; Bearden, Henning, Bearden & Moffat, 2004; Hill, Halcomb & Stevens, 2003; Borrani et al, 2001; Perry, Betik, Candau, Rouillon & Hughson, 2001; Saunders et al, 2000; Gaesser and Poole, 1996; Casaburi, Storer, Bend-Dov & Wasserman, 1987). They tested 6 male trained runners (31.2 ± 5.4 years) on a continuous incremental exercise test to voluntary exhaustion, on three separate occasions wearing compression tights, classic elastic tights, or conventional shorts. Results showed energy cost of running to be significantly lower ($p < 0.05$) whilst wearing compression tights and conventional tights when compared to conventional shorts. This would suggest that even conventional tights offer some benefits associated with compression garments. They then studied 6 other male runners (26.7 ± 2.9 years) during 15 minutes of constant running at 80% of $\dot{V}O_2max$, again with the same clothing conditions. The results show the $\dot{V}O_2$ slow component to be significantly lower whilst wearing compression tights compared to shorts ($p = 0.01$) and compared to elastic tights ($p = 0.4$).

This research by Bringard, Perry and Bulleye (2006) needs careful consideration in a number of aspects. Firstly the sample size is fairly small, which is highlighted by the results for energy consumption only having a statistical power of 0.53 (i.e. 53% chance of detecting an effect) (Field, 2005, p.34; Pallant, 2005, p.199). This is also related to the second point in that this study used a repeated measures ANOVA with post-hoc across the three clothing conditions. This would make multiple comparisons which would mean the Bonferonni adjustment would need to be made to avoid committing a Type I error. A significance level of $p = 0.016$ should therefore be set, which would question the results reported in this study.

Other fatigue benefits of compression garments include increased oxygen delivery to working muscles, increased microcirculation (Fusco & Bohm, 2002) and deep tissue oxygenation (Agu, Baker & Seifalian, 2004) within the working muscles. Agu, Baker and Seifalian (2004) tested the effects of graduated compression stockings on calf oxygenation in patients suffering from chronic venous insufficiency. Deoxyhemoglobin content within the muscles was significantly reduced whilst wearing high compression stockings. Limb oxygenation, as measured by oxyhemoglobin, was significantly improved ($p = 0.03$) during walking exercise by wearing high compression stockings. However, the results of this study although significant for participants with chronic venous insufficiency, compression stockings may not produce any significant benefit for participants with a healthy venous system.

Lactate removal from the muscles has been suggested to be enhanced by compression garments due to an increased venous return (Bringard, Perrey, & Belluye, 2006; Lambert & Chow, 2004; Higgins, 2004; Fusco & Bohm, 2002; Kraemer et al, 1998a). Research by Lambert and Chow (2004) showed that for the same peak lactate values and $\dot{V}O_2max$, subjects wearing SportSkins™ compression garments showed significant improvements in time to exhaustion. This study tested 21 male elite rugby players ($23 \pm 3.1$ years) during an incremental treadmill test to exhaustion. Participants then completed a second treadmill run 45 minutes later at the finishing speed and slope of the first test. Participants were divided into two groups, one that wore SportSkins™ graduated compression garments (top and bottoms) and the other group wore no SportSkins™. Results showed blood lactate concentrations to be significantly reduced ($p = 0.05$) at 15 minutes post exercise for the group wearing SportSkins™ ($9.43 \pm 2.98$ mmol·l$^{-1}$ and $7.0 \pm 2.45$ mmol·l$^{-1}$ for control group and SportSkins™ respectively). Time to exhaustion during the second test was also significantly improved ($p = 0.0351$) for the group wearing SportSkins™ compared to the control group ($170.7 \pm 38.6$ seconds and $136.6 \pm 30.1$ seconds for SportSkins™ and control respectively). One possible problem with this research is that participants did not act as their own controls. Therefore, what is to say that the group wearing the SportSkins™ may have performed better than the control group even if they were not wearing the SportSkins™. A repeated measures design should have been implemented. Another possible problem with this research is the chance that there may be some bias involved, as it is possibly an in house study, as one of the authors was an employee of the company (Skins™) at the time of study.

The study by Bringard, Perry and Bulleye (2006) suggest a reduction in blood lactate whilst wearing compression tights based on a reduction in the $\dot{V}O_2$ slow component. The $\dot{V}O_2$ slow component is the delayed rise in oxygen uptake ($\dot{V}O_2$) experienced during submaximal heavy constant running, occuring 2-3 minutes after the onset of exercise and causes oxygen uptake to rise above the expected energy requirement (Bringard, Perry & Bulleye, 2006; Bearden et al, 2004; Hill, Halcomb & Stevens, 2003; Borrani et al, 2001; Perry et al, 2001; Saunders et al, 2000; Gaesser & Poole, 1996; Casaburi et al, 1987). This close relationship between the $\dot{V}O_2$ slow component and the amount of blood lactate was highlighted in cross sectional studies by Casaburi et al (1987) and Gaesser and Poole (1996). More recently Saunders et al (2000) suggest that increased motor unit recruitment is responsible for the close relationship between the $\dot{V}O_2$ slow component and an increase in blood lactate.

Further research by Lambert (2005a) presented claims that SportSkins™ compression garments appear to promote oxygen utilisation during exercise, as indicated by significant improvements in anaerobic threshold and $\dot{V}O_2max$ of 40% and 10% respectively. This study used sample size of 5 participants, performing two graded exercise tests seven days apart. Participants acted as their own controls by either wearing SportSkins™ compression garments or not. Results show $\dot{V}O_2max$ to be significantly improved ($3.68 \pm 0.9$ L•min$^{-1}$ and $3.36 \pm 0.9$ L•min$^{-1}$ for SportSkins™ and control respectively, $p = 0.004$). Anaerobic threshold significantly improved from $2.07 \pm 0.8$ L•min$^{-1}$ to $2.77 \pm 0.6$ L•min$^{-1}$ by wearing SportSkins™. Again, this study could show a bias as the author is employed by the company providing the graduated compression garment (Skins™), which could question the credibility of the results.

A study by Higgins, Naughton and Burgess (2007) using SportSkins™ graduated compression garments, found that 11 state level netball players ($22.6 \pm 4.6$ years) were able to cover a greater distance at a higher intensity whilst wearing the graduated compression garments, during netball specific circuits. The netball specific circuits were made up of six small drills, designed to replicate work interval and motion patterns in netball, identified using motion analysis of a competitive game of netball. Drill one consisted of a shuffle through a ladder followed by a 3.5 metre sprint and a leap, as if catching the ball. Drill two was a zig zag lead run followed by a 3.5 metre sprint and a leap, as if catching the ball. Drill three was a defend drill over a short distance incorporating short bursts of movements with pivoting and changes in direction. Drill four was an attacking drill consisting of a zig zag run followed by a 3 metre sprint, then a vertical jump as if receiving the ball. Drill five was a pass and move drill over 4 metres, again with a leap on reception of the ball. Drill six was a one on one drill, where participants paired up against each other. These six drills were randomised into a set circuit, together with rest/walk/jog periods, to replicate the work to rest ratio of 1:4 seen in competitive netball games. These improvements whilst wearing graduated compression garments equated to a 20% improvement over a control clothing condition (netball attire) and a 34% improvement over a placebo clothing condition (light compression elastic tights), However this was not deemed to be significant ($p = 0.09$).

Another theory proposed for the fatigue reducing effects of compression garments is through the reduction in muscle vibration and oscillation during exercise (Doan et al, 2003; Kraemer, Bush, & Newton, 1997; Shim et al, 2001; Bringard, Perrey, & Belluye, 2006). The effect of external vibration on the body is to stimulate involuntary muscle contraction. Due to this subconscious nature of muscle contraction, many more fibres are recruited than in a conscious, voluntary contraction (Issurin & Tenenbaum, 1999; Sidhu, 2008). This enables muscles to be used more quickly and efficiently, thus increasing the muscles ability to generate force (Paradisis & Zacharogiannis, 2007; Lamont, Cramer, Gayaud, Acree & Bemben, 2006; Cormie, Deane, Triplett & McBride, 2006; Bosco, Cardinale & Tsarpela, 1999; Bosco et al, 2000; Rittweger, Schiessl & Felsenberg, 2001; Rittweger et al, 2002; Abercromby, Amonette, Paloski & Hinman, 2005; Amonette, Abercromby, Hinman & Paloski, 2005). Whilst this is beneficial for short duration power activities (Tihanyi, Horváth, Fazekas, Hortobágyi & Tihanyi, 2007; Bosco et al, 2000; Bosco et al, 1999) and also as a training aid (Bautmans, van

Hees, Lemper & Mets, 2005), prolonged exposure to muscle vibration has been shown to increase muscle fatigue (Adamo, Martin & Johnson, 2002; Samuelson, Jorfeldt & Ahlborg, 1989), reduce motor unit firing rates and muscle contraction force (Bongiovanni, Hagbarth & Stjernberg, 1990; Neckling, Lundborg & Fridén, 2002), decrease nerve conduction velocity (Cardinale & Wakeling, 2005), and can affect perception rates (Dupuis & Jansen, 1981). The body's natural response to vibration is to use muscle contraction in order to dampen the effects (Cardinale & Wakeling, 2005; Wakeling, Nigg & Rozitis, 2002). This involves an active cross bridge cycling between the actin and myosin myofilaments (Rack & Westbury, 1974), as more vibration is absorbed by an activated muscle (Ettema & Huijing, 1994; Wakeling & Nigg, 2001; Wakeling, Nigg & Rozitis, 2002).

Reserach by Doan et al (2003) found that significant reductions in muscle oscillation upon landing from a vertical jump resulted in significant improvements in repetitive jump performance. They tested ten male (20 ± 0.9 years) and ten female (19.2 ± 1.3 years) track athletes specialising in sprint and jump events. Participants wore either lose fitting shorts or strong compression shorts (75% neoprene, 25% butyl rubber), and acted as their own controls. Participants were instructed to dip down to a comfortable depth and then jump for maximal height, whilst keeping their hands on their hips throughout. Verticle jumps were repeated until height stopped increasing. A video camera was positioned to record the sagital plane view of the participant. Reflective markers positioned on the leg, at the greater trochanter, the lateral epicondyle of the femur, and the antero-lateral aspect of the thigh, were used to assess muscle oscillation upon landing. Analysis showed significantly reduced ($p = 0.013$ for both groups) longitudinal (0.32 cm) and anterior-posterior (0.40 cm) muscle oscillation upon landing from maximal vertical jumps whilst wearing compression garments.

Bringard, Perrey, and Belluye (2006) also found improvements during sub maximal running. By reducing muscle oscilation the compression garments supported the muscle fibres in their contraction direction (Bringard, Perrey, & Belluye, 2006). This is thought to optimize neurotransmission and mechanics at a molecular level (McComas, 1996), leading to enhanced technique and increased efficiency of muscle contraction, thus reducing fatigue (Bringard, Perrey, & Belluye, 2006; Doan et al, 2003; Kraemer, Bush, & Newton, 1997). Research by Samuelson, Jorfeldt and Ahlborg (1989) on the effects of vibration on muscle endurance, found vibration to have a detrimental effect. They tested 14 males (age 20) performing maximal isometric and sustained knee extensions. Vibration was applied to the ankle at 20 Hz and the acceleration 20 $m/s^2$. The endurance was defined as the time taken for the force produced by the participants to reduce by 10%. Mean endurance times without vibration were 22.5 seconds and 15.8 seconds with vibration. Therefore vibration reduced endurance by 6.7 ± 1.84 seconds, which was significant ($p = 0.005$).

#### 4.2.2. Power output

Research by Doan et al (2003) and Shim et al (2001) reported that compression shorts can significantly improve ($p = 0.015$) power output as tested by performing single maximal vertical jumps. Jump height increased from 0.461 metres for the control group to 0.485 metres for the compression group. It is suggested that this may be due to the elasticity of the compression garments increasing the propulsive force. It was also noted that subjects were able to squat significantly lower ($p = 0.16$) whilst wearing compression shorts, 0.270 metres for the control group and 0.288 metres for the compression group. It is thought that lower squat depth, or more optimal squat depth, was a result of the mechanical support offered by the compression garment, thus resulting in greater power generation during the concentric phase of the jump (Doan et al, 2003).

Other studies (Kraemer et al, 1996; Lambert, 2005b; Kraemer, Bush, & Newton, 1997; Argus, 2005; Higgins, 2004) have not been able to replicate such significant direct power improvements as shown in this study by Doan et al (2003). It is suggested that this may be because the shorts used in this study were of a neoprene and butyl rubber mix, much thicker than normal compression shorts, thus providing significant additional elastic force. These other studies (Kraemer et al, 1996; Lambert, 2005b; Kraemer, Bush, & Newton, 1997; Argus, 2005; Higgins, 2004) demonstrate the power benefits of compression garments in terms of reduced fatigue. Kraemer et al (1996) showed that, amongst 18 males and 18 female varsity volleyball players, mean force and power output during sets of jumps were significantly higher ($p < 0.05$) whilst wearing compression shorts during 10 consecutive countermovement jumps.

Lambert (2005b) showed that the number of leg press repetitions to fatigue was significantly improved ($p = 0.03$) whilst wearing SportSkins™ graduated compression garments compared to not wearing graduated compression garments. Four participants performed repeated maximal leg presses to failure. Participants acted as their own controls in a randomised protocol between wearing and not wearing SportSkins™ graduated compression garments. The mean difference between groups for leg press repetitions was 18.75 ± 3.77 and 16.25 ± 5.05 for SportSkins™ graduated compression garments and no SportSkins™ respectively ($p = 0.03$). Again this research has the problems of possibly being an in house study conducted by Skins™, and also a small sample size. However this may only be a pilot study.

Unpublished research by Argus (2005) and Higgins (2004) show positive effects of compression garments on repeated sprint ability, indicated by a reduced drop off time between the first sprint and the last, although significance was not reached. In the case of Higgins (2004), this was probably due to the fact that it was a pilot study involving only four subjects.

Argus (2005) tested 19 male recreational athletes (21.9 ± 3.3 years) randomly split into two test groups, graduated compression garments ($n = 10$) and control ($n = 9$). Participants were required to perform a repeated sprint test consisting of 12 repetitions over 20 metres, departing every 20 seconds. Participants then rested for 10 minutes before completing an isokinetic fatigue protocol of ten sets of ten maximal concentric and eccentric contractions of the knee flexors. Participants performed these test on three consecutive days and then another test session four days later. Participants in the graduated compression group wore their garments for 12 hours after each testing session. Sprint times reduced for the compression group from day one to day two whilst they increased for the control group (-0.5 ± 3.6% and +0.6 ± 2.6% for compression and control respectively). On day three the compression group further reduced sprint times whilst the control group further increased sprint times (-0.6 ± 3.6% and +1.5 ± 3.1% for compression and control respectively). Both groups reduced sprint times on day seven, compared with base line results. The results of this study suggest that benefits of graduated compression garments may be more to do with recovery, rather than direct improvements in performance, indicated by no difference in baseline measures between the two groups in this study. The effects of graduated compression garments may become more apparent in the long term rather than short term.

### 4.2.3. Recovery

Argus (2005) as mentioned above has shown that graduated compression garments help to improve repeated sprint performance on consecutive days when worn up to 12 hours after exercise. It is suggested that compression garments may improve recovery by increasing venous blood flow in the post exercise period, resulting in greater lactate removal and oxidation (Berry & McMurray, 1987; Chatard et al, 2004; Gill, Beaven & Cook, 2006). The results presented by Argus (2005) suggest a relatively long term effect of compression garments, i.e. over a 24 hour period. Previous research by Chatard et al (2004) tested the effects of graduated compression garments during an 80 minute recovery period between two bouts of maximal exercise. Twelve elderly trained cyclists (63 ± 3 years) performed two 5 minute maximal exercise test on a cycle ergometer separated by an 80 minute recovery period. During recovery participants sat with their legs elevated on a chair and randomly wore or did not wear graduated compression tights. During recovery, blood lactate concentrations and the hematocrit were significantly lower ($p < 0.01$) when wearing graduated compression garments compared to not wearing compression garments. Performance during the second test was also enhanced by 2.1% for the graduated compression garments compared to the control group.

Creatine kinase concentrations in the interstitial fluid and blood following high intensity eccentric exercise, is considered a general marker of muscle damage (Kraemer et al, 2001; Komulainen, Takala & Vihko, 1995), and have been shown to be reduced whilst wearing compression garments following exercise (Kraemer et al, 2001; Gill, Beaven & Cook, 2006). Gill, Beaven and Cook (2006) tested four different recovery strategies on 23 elite male rugby players (25 ± 3 years). Participants were randomly assigned to one of four recovery groups: passive recovery, active recovery, contrast water therapy, and graduated compression garments. Mean creatine kinase concentrations in the interstitial fluid tested pre and post rugby match were significantly different ($p < 0.01$) (1023.0 U/l and 2194.0 U/l for pre and post match respectively). Passive recovery resulted in the worse recovery of creatine kinase levels (39% recovery 84 hours post match, $p < 0.05$). Recovery rates of creatine kinase for active recovery, contrast water therapy, and graduated compression garments were 88.2%, 85.0% and 84.4% respectively ($p < 0.05$). This study shows that graduated compression garments significantly reduce symptoms associated with muscle damage (creatine kinase) in the post exercise period. Some possible problems with this research are the fact that a number of participants were unable to complete the recovery strategies due to injury, non-selection for games, or lack of match time. There is also possible problem with the variability in intensity of matches played by the participants, and there also may be variability in regards to position on the pitch. This is supported by Duffield and Portus (2007) who found creatine kinase and ratings of muscle soreness to be significantly lower ($p < 0.05$) 24 hours after a 30 minute repeated sprint protocol, from wearing compression garments.

Muscle soreness which commonly follows eccentric exercise is known as delayed onset muscle soreness (DOMS) (Connolly, Sayers & McHugh, 2003; Trenell, Rooney, Sue & Thompson, 2006). Compression garments have been shown to alleviate symptoms associated with DOMS, such as oedema, strength loss, stiffness, and subjective sensations of muscle soreness (Kraemer et al, 2001). Research by Ali, Caine and Snow (2007) tested 14 recreational runners wearing graduated compression stockings during and after a 10km race. They found DOMS to be significantly reduced ($p < 0.05$) 24 hours after a 10km road run whilst wearing graduated compression stockings compared to a control of not wearing compression stockings.

### 4.2.4. Body temperature

Compression garments have been shown to increase muscle temperatures (Doan et al, 2003; Shim et al, 2001) up to what is considered an optimum temperature for performance of 38.5ºC (Doan et al, 2003), resulting in improvements in performance, and also reducing risk of injury. The high compression shorts used in this study caused a significant increase ($p = 0.003$) in skin temperature compared with loose fitting shorts during a five minute warm up. It is suggest that this reduction in warm up time will enhance muscle performance. But, it is also noted that the garment may also increase temperatures over what is deemed optimal, possibly being detrimental to performance.

Research by Houghton, Dawson and Maloney (2007) researched the possibility that wearing compression garments as a base layer could possibly increase heat storage. They tested ten field hockey players wearing compression shorts and t-shirt underneath their normal hockey attire against them just wearing their normal match day attire. Testing comprised of the Loughborough intermittent shuttle test being performed 4 times for each of the testing sessions. Testing took place in an indoor gymnasium with an ambient temperature of 17 ºC and relative humidity of 60%. Results showed a significant increase ($p < 0.05$) in skin temperature for the compression garments compared to the normal match day attire. There was no significant difference ($p > 0.05$) in core temperature, suggesting no direct detriment to performance, but elevated skin temperatures may affect subjects' preference for wearing compression garments under normal sporting attire. It may have been beneficial in this case to have carried out a field based study, in order to expose the compression garments to the environment in which they will most commonly be used.

Gavin, Babington, Harms, Ardelt, Tanner and Stager (2001) tested a t-shirt and cycling short combination claimed by the manufacturer to promote sweat evaporation. This was tested against a cotton t-shirt and cycling short combination and a lycra racing swimsuit. Eight males completed three submaximal treadmill tests, each time whilst wearing a different clothing combination. Testing consisted of 20 minutes rest, 30 minutes of treadmill running at 70% of $\dot{V}O_2max$, 15 minutes of treadmill walking at 40% $\dot{V}O_2max$, followed by 15 minutes seated rest. Environmental temperature was set at 30 ºC ± 1 ºC and humidity was 35 ± 5%. A simulated wind was generated during rest, running and walking of 3 $km{\cdot}h^{-1}$, 11 $km{\cdot}h^{-1}$ and 6 $km{\cdot}h^{-1}$ respectively. The findings of this study were that a synthetic fabric designed to promote evaporation did not provide any thermoregulatory, physiological, or comfort advantage during exercise and recovery when compared to a normal cotton ensemble. The relatively high environmental temperature used in this study may have been too much to highlight any possible fabric advantages. Although, the use of a simulated wind would have provided additional help in heat transfer and sweat evaporation.

Research shows muscle function can be positively or negatively effected by changes in temperature (Doan et al, 2003; Bergh & Ekblom, 1979a; Bergh & Ekblom, 1979b; Sargeant, 1987; Ferretti, Ishii, Moia & Cerretelli, 1991; Bennet, 1985; Oksa, Rintamäki & Rissanen, 1997; Mohr, Krustrup, Nybo, Nielsen & Bangsbo, 2004; Stewart, Macaluso & De Vito, 2003; Mohr, Krustrup & Bangsbo, 2005; Faccioni, 2004; Bergh, 1980; Wade et al, 2000). Mohr et at (2004) tested the effects of a half time break in football on muscle temperature and its effects on sprint performance. Participants ($n = 16$) were randomly allocated to two groups, passive recovery during half time, and low intensity exercise during the half time break. Muscle temperature in the passive recovery group significantly reduced ($p < 0.05$) from 39.4 ± 0.2 ºC at the end of the first half to 37.4 ± 0.2 ºC during half time. The group practicing low intensity exercise during half time had similar muscle temperature at the end of the first half to the passive group, but muscle temperatures were significantly higher ($p < 0.05$) by 2.1 ± 0.1 ºC prior to the start of the second half. At the start of the second half sprint performance was significantly reduced ($p < 0.05$) by 2.4% in the passive recovery group, but remained unchanged in the light exercise group. The reduction in muscle temperature in the passive recovery was significantly correlated to the decrease in sprint performance ($r = 0.60$, $p < 0.05$).

Bergh and Ekblom (1979a) found that performance of short term power events, such as sprinting or jumping, is reduced below, and enhanced above, normal muscle temperatures. Studies using body cooling have found decreases in power output and reduced times to muscle fatigue (Oksa, Rintamäki & Rissanen, 1997; Ferretti et al, 1991; Wade et al, 2000). Feretti et al (1991) tested the effects of reducing muscle temperature using a temperature controlled water bath. Six participants performed a series of standing vertical jumps. Without muscle cooling muscle tremperature ws 35.8 ± 0.7 ºC and muscle power was 51.6 ± 8.7 $W{\cdot}kg^{-1}$. After 90 minutes of muscle cooling in a water bath (20 ± 0.1 ºC) muscle temperature was reduced by 8 ºC and jump performance was 27% lower.

Studies using body warming, show improvements in power output through increases in rate and force of muscle contraction (Stewart, Macaluso & De Vito, 2003; Sargeant, 1987; Faccioni, 2004; Bergh, 1980; Bergh & Ekblom, 1979a; Bergh & Ekblom, 1979b), which is thought to be due to improved mechanical efficiency (Faccioni, 2004, Bergh, 1980) and faster activation of muscle fibres (Stewart, Macaluso & De Vito, 2003). Sargeant (1987) found that warming the legs for 45 minutes, at 44 ºC in a water bath, resulted in an 11% increase in maximal peak force and power during 20 second maximal sprint efforts on a cycle ergometer. Cooling the legs for 45 minutes at 18 ºC and 12 ºC resulted in reductions in maximal peak force and power of 12% and 21% respectively.

Stewart, Macaluso and De Vito (2003) found that warming up on a cycle ergometer at 70% ventilatory threshold significantly increased ($p < 0.05$) muscle temperature compared to a control of no warm up (36.8 ± 0.5 ºC  and 33.8 ± 0.4 ºC repectively). Instantaneous power output during the squat jump was significantly higher ($p < 0.05$) in the warm up group than the control (3569 ± 919 watts and 3324 ± 866 watts respectively). Some possible problems with this research is firstly the sample size of eight participants is a bit low to be considered as having sufficient statistical power. Also both tests were performed on the same day. Therefore if participants did the control test first then it could be argued that this enabled them to have a practice at the jump test, therefore performing better the second time during the warm up test. If participants did the warm up test first, then this may have reduced performance later in the day for the control test.

#### 4.2.5. Proprioception

It is suggested by manufacturers of certain brands of compression clothing (Skins™; Canterbury, BSc) that their products may improve skill performance as a result of improved proprioception. Proprioception is the awareness and sensation of one's body posture and position in space (Fusco & Bohm, 2002). Proprioception is an automatic sensitivity mechanism sending messages through the central nervous system, which is then relayed to the rest of the body as to how to react (Nottingham, 2006). Sensory receptors in the muscle, joint and connective tissue enable the body to process information from a variety of stimuli, and turn that information into an action (Nottingham, 2006). Kinesthetic awareness is the ability to know where body parts are in a 3-dimentional space (Quinn, 2008), and is closely related to proprioception (Nottingham, 2006). It is thought that improved neurotransmission and mechanics at a molecular level (McComas, 1996) leads to more efficient muscle contraction, muscle co-ordination, balance, all of which could contribute to an improvement in skill. Previous studies have focused on knee movement and reproduction of knee angles using memory and feeling (Kuster, Grob, Kuster, Wood & Gachter, 1999; Perlau, Frank & Fick, 1995; Barrack, Skinner, Cook & Haddad, 1983).

Perlau, Frank and Fick (1995) tested a population of 54 participants (22 to 40 years) on the effects of elastic bandages on knee proprioception. Participants were asked to identify a prior set joint angle as their knee was passively extended. Participants were tested without the elastic bandage, immediately after bandage application, one hour after bandage wear, and after removal of the bandage. Results showed elastic bandages to significantly improve ($p < 0.05$) knee joint proprioception during both stages of its use. The mean decrease in joint inaccuracy was 1.0 º, which equated to a 25% improvement in joint position identification.

Researchers suggest compression does indeed improve proprioception (Bringard, Perry & Belluye, 2006; Doan et al, 2003; Fusco & Bohm, 2002; Kraemer, Bush & Newton, 1997; Barrack et al, 1983), muscle co-ordination (Bringard, Perry & Belluye, 2006; Kuster et al, 1999), balance (Kuster et al, 1999) and may improve technique (Perlau, Frank & Fick, 1995).

Bringard, Perry and Bulleye (2006) suggest that an increase in propriception may have contributed to the reduction in the energy cost of running highlighted in their study. They suggest that the compression tights worn in their study may assist motion pattern by increasing proprioception, muscle coordination, and propulsive force. Doan et al (2003) also suggests proprioception may have contributed to a significant improvement ($p = 0.015$) in vertical counter movement jump height, whilst wearing high compression shorts in their study. However, benefits of proprioception in these two studies are more speculation rather than quantitative evidence.

Another proposed benefit of compression on proprioception, balance, and muscle coordination is through a reduction in muscle vibration. Research has shown muscle vibration to have detrimental effects on balance (Sorensen, Hollands & Patla, 2002), joint position (Radovanović et al, 1998; Eklund, 1972), motor unit firing (Bongiovanni, Hagbarth & Stjernberg, 1990; Neckling, Lundborg & Fridén, 2002) and nerve conduction velocity (Cardinale & Wakeling, 2005). It has been suggested that compression garments can improve performance by reducing muscle vibration and oscillation (Doan et al, 2003; Kraemer, Bush, & Newton, 1997; Shim et al, 2001; Bringard, Perrey, & Belluye, 2006). This theory would support the use of graduated compression garments in improving skill performance.

# CHAPTER 2

# METHOD

## 5. Participants

Ethical approval for this study was given by the Faculty of Applied and Health Sciences' Research Ethics Committee, at the University of Chester (see appendix 1).

Twenty three English Hockey League North standard male field-hockey players were the target population for testing. Participants were recruited from Telford and Wrekin Hockey club, already known by the researcher (see appendix 2 for request and acceptance letters).

In order to calculate the required sample size for this study a power analysis was carried out using the G*Power 3.0.4 software (Erdfelder, Faul & Buchner, 1996) down loaded from the internet (http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/) (see appendix 3 for detailed power analysis). Results of the power analysis stated that 14 participants would be needed, tested three times, in order for the study to be considered as having sufficient power.

Each participant was given a participant information sheet regarding the study (see appendix 4) and all gave their written informed consent prior to involvement in the research (see appendix 5).

## 6. Experimental Design

Each participant was required to complete three testing sessions, each time whilst wearing a different selection of clothing. The order in which each clothing trial was tested on individual participants was randomized. This was done by pulling the three clothing trials out of a hat, and that order was allocated to participants as they were recruited (see appendix 6).

- Control: 65% Polyester, 35% Cotton playing polo shirt. Playing shorts. Playing socks.
- Placebo: (94% cotton, 6% lycra).
- Graduated compression garments. SportSkins™ (76% Nylon, 24% Spandex).

The graduated compression clothing and placebo clothing consisted of a long sleeve top, shorts and socks. The long sleeve top covered the body from the neck to the waist and also the arms to the wrist. The shorts covered from the waist to just above the knee. The socks covered from just below the knee to the ankle. Both the placebo and the graduated compression garments clothing conditions were worn under the control clothing condition.

Testing took place on the astro-turf pitch at Telford and Wrekin Hockey Club, situated behind St Georges Sports and Social Club, Church Road, St Georges, TF2 9LU (see appendix 7 for risk assessment forms as part of the ethical approval process).

Participants were required to present themselves for testing in a two hour postprandial condition, and to have refrained from taking part in strenuous exercise 24 hours prior to testing (Gore, 2000).

Tests were separated by a minimum of one day to allow adequate recovery for participants. The third testing session was kept as close to two weeks as possible from the first test session. This was to try and avoid any possible physiological adaptations occurring, positive or negative.

**Table 1**: Test procedure.

| | TIME | PROCEDURE |
|---|---|---|
| Arrival | | • Arrival of male subject in 2 hour postprandial condition having refrained from exercise 24 hours prior to testing. |
| | 10mins* | • Subject is required to fill out informed consent form and health questionnaire (see Appendix 2, 3 and 4) (Familiarization session only).<br>• Any doubts or queries the subject has regarding any of the testing will be addressed during this time. |
| | 10mins* | • Anthropometric Characteristics gathered (Familiarization session only).<br>• Weigh subject .<br>• Subject is required to then dress in the randomly selected clothing combination. |
| Rest | 15mins | • Seated rest.<br>• Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored on 0min and 15min. |
| Warm Up | 15mins | • Subjects pre match warm up<br>• Including runs through the hockey skill test and sprint test.<br>• Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored post warm up. |
| Skill Test | 1min 30secs* | • Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored on completion. |
| Sprint Test | 3mins 30secs* | • Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored on completion of the $7^{th}$ sprint. |
| Intermittent Endurance Test | 16mins 30secs | • Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored post test. |
| Skill Test | 1min 30secs* | • Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored on completion. |
| Sprint Test | 3mins 30secs* | • Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored on completion of the $7^{th}$ sprint. |
| Recovery | 20mins | • Seated recovery<br>• Heart rate, body temperature, lactate, RPE and subjective ratings will be monitored on 20min. |
| End of test | | • Weigh subject |

*Times are approximate and may vary.

### 6.1. Familiarisation sessions

Participants attended two familiarisation sessions prior to testing. Studies have found that performing a novel task that an individual is unfamiliar with requires two familiarisation trials in order to produce stable values on subsequent days (Argus, 2005; Capriotti, Sherman & Lamb, 1999; Martin, Diedrich & Coyle, 2000). The familiarisation sessions consisted of participants getting to practice the full test procedure (see table 1) to prevent any bias caused by learning once data collection commenced (Welsh et al, 2002).

Prior to partaking in any activity participants were required to complete a pre-activity health status appraisal (see appendix 8). Participants were able to ask any questions regarding the study and were also informed they were free to drop out at any time.

### 6.2. Warm up

Participants warmed up for 15 minutes prior to testing. The warm up routine was that used by the participants before their normal training sessions and pre match. This was a set warm up of steady paced running, dynamic stretching and speed work. Participants were allowed practice runs through the sprint test and hockey skill test as part of their warm up to ensure maximal performance once testing began (Bangsbo, 1994) (see appendix 9).

### 6.3. Field Hockey Skill Test

The field hockey skill test (see figure 1) (see appendix 10 for full instructions) as developed by Sunderland, Cooke, Milne, Pout and Nevill (2006) has been found to be both a reliable and valid skill test for the modern game of hockey ($r = 0.96$, $p < 0.0001$). The mean difference and limits of agreement for the overall skill test performance was 0.03 ± 5.11 seconds. The test requires the participant to dribble a hockey ball around a series of cones in a specific sequence. On passing the last cone the subject is given a command, for this study it was a verbal command of a colour, which corresponded to each half of the goal. After completing a pass off a rebound board, the participant was required to go on to shoot at the opposite side of the goal to which the command was given. The time taken between passing the last cone and the ball hitting the goal back board was considered the decision time. The test was continuous until six shots have been completed. A two second time penalty was awarded for hitting cones, the ball hitting feet, missed shots, or shooting at the wrong side of the goal. Thus the test incorporated dribbling, passing, shooting and decision making elements. Participants were given verbal encouragement in order to complete the test as quickly as possible.

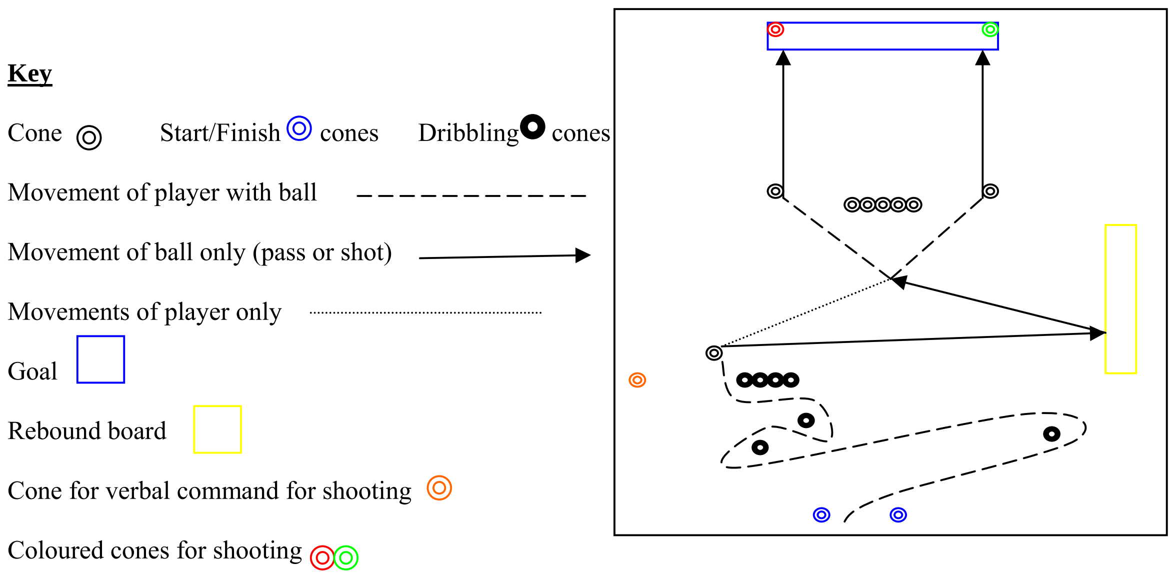


**Figure 1:** Field hockey skill test (Sunderland et al, 2006).

### 6.4. Sprint Test (Bangsbo, 1994, p.82)

The proposed sprint test for this study was developed by Jens Bangsbo for use on football players. Sprint ability is considered very important in a team game and a result may be decided on an individual's ability to run faster than their opponent in a given situation. More important, repeated sprint ability is a distinguishing factor of a team game athlete such as field-hockey, football, or rugby (Psotta, Blahus, Cochrane & Martin, 2005; Glaister, 2005; Spencer, Bishop, Dawson & Goodman, 2005; Bishop & Spencer, 2004; Spencer, Bishop & Lawrence, 2004, Bishop, Spencer, Duffield & Lawrence, 2001). Sprinting in team games is very unpredictable, so the ability to recover quickly following high intensity exercise is very important (Bangsbo, 1994, p.82). During a team game like field-hockey or football a player will be expected to sprint up to 40 meters during the game on a number of occasions (Gore, 2000, p.289; Bangsbo, 1994, p.82), and will often include changes in direction in order to get away from an opponent (Bangsbo, 1994, p.82).

With these above factors considered, Jens Bangsbo designed a sprint test which can be seen in figure 2 and also in appendix 11. This test was found to be highly reliable ($r = -0.298$, $p = 0.516$) by Wragg, Maxwell and Doust (2000). The test consisted of a 30 meter sprint with a change of direction, followed by 25 seconds of low-intensity running. The test was completed when participants had performed 7 sprints. Participants were given verbal encouragement to perform maximally during the sprints.

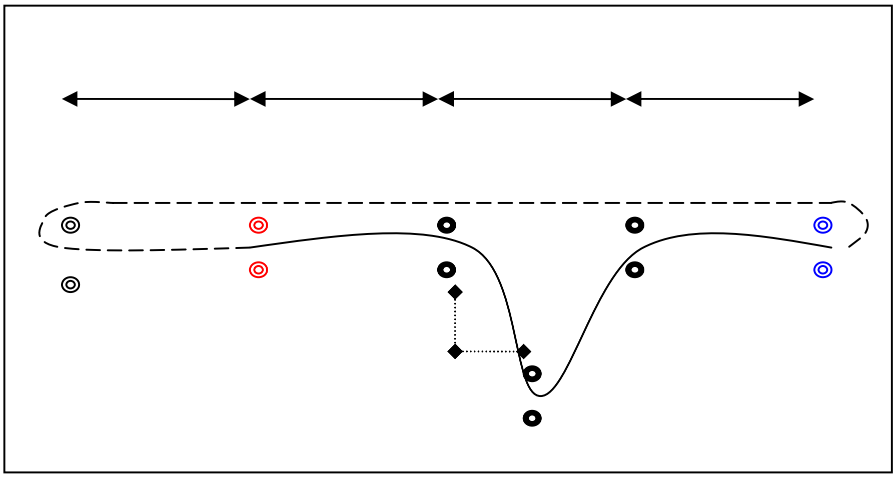

**Figure 2:** Repeated sprint ability test (Bangsbo, 1994, p.82).

**Key**

Cone ◎ Start cones ◎ Finish cones ◎

Sprint

Recovery

10 metres

5 metres

### 6.5. Intermittent Endurance Test (Bangsbo, 1994, p. 88)

The intermittent endurance was designed by Jens Bangsbo in order to test a football player's endurance capacity. The test incorporates a number of activity patterns thought to reflect the intermittent activity profile of a football match. The test can be seen in figure 3 and its full procedure can be seen in appendix 12. The test consists of periods of high intensity running for 15 seconds, followed by 10 seconds of jogging, and continues this way until forty periods of high intensity running (10 minutes) and thirty nine periods of jogging (6.5 minutes) have been completed. The test result is the distance (metres) covered during the forty periods of high intensity running. Participants were instructed to cover as much distance as possible during these periods.

The test result is calculated by multiplying the number of laps completed by 160 (m) (i.e. the distance of one lap). The distance covered during the last lap is then added to the laps total to give a final distance covered. The distance of the last lap is determined by the finishing cone number (see figure 3), which is converted to a distance using table 6 presented in appendix 12.

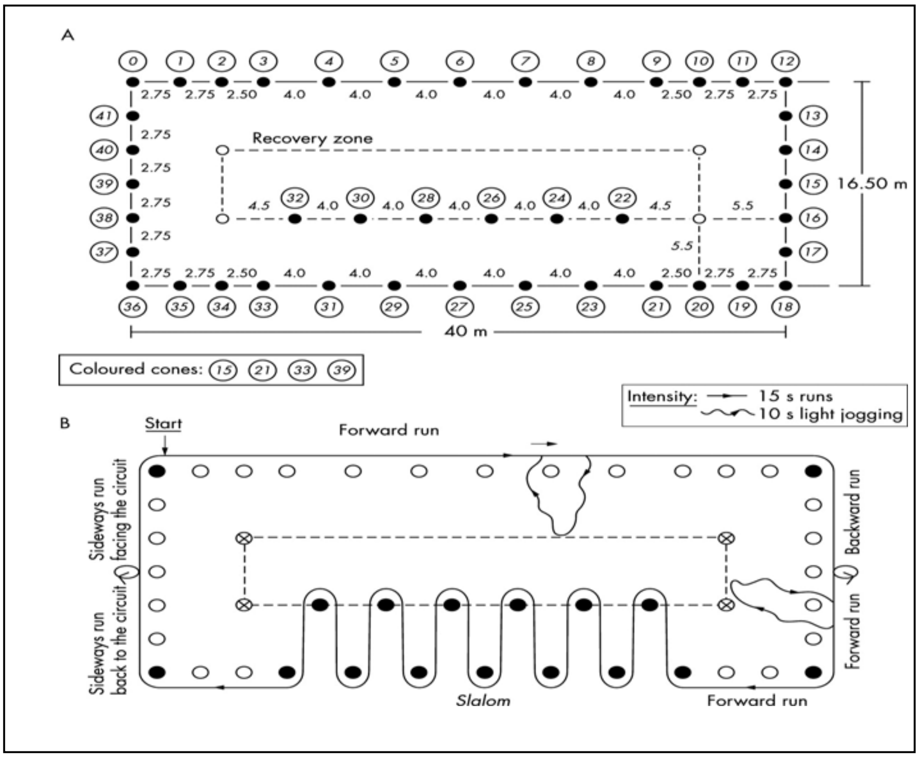


**Figure 3:** Intermittent endurance test (Bangsbo, 1994, p. 88).

### 6.6. Measurements

#### 6.6.1. Anthropometric characteristics

These characteristics were be obtained during the participants' first visit and consisted of height, weight and chest size.

These three measurements were then used to determine the size of the SportSkins™ graduated compression garments for each participant (see appendix 13 for size charts, figures 17, 18 and 19).

***Height (cm)***

Height was measured using a free-standing height stadiometer (Seca, Germany). Stature was measured with participants stood tall, barefoot with their heels, buttocks and upper back against a wall. Participants were instructed to keep their heads in the Frankfurt plane position, with their arms relaxed and by their sides. Participants were then required to inhale and stretch upwards whilst the headboard of the stadiometer was slid down to the cranial vertex. The measurement was then taken to the nearest centimeter (www.ISAKonline.com).

***Body mass (kg)***

Body mass was measured using a set of calibrated weighing scales (Salter Model No. 109, England). Participants were weighed whilst wearing minimal clothing. Measurement was recorded to the nearest 0.1kg.

***Chest size (cm)***

Chest circumference measurement was taken at the level of the Mesosternale (see figure 4) using a non-stretch flexible tape measure. Participants were initially required to raise their arms to allow the tape to be passed around the thorax, and then lowered before measurement is recorded. Participants were then instructed to inhale and then to exhale normally, not forced. Measurement was then recorded to the nearest 0.5 cm at the end of the expiration (www.ISAKonline.com).

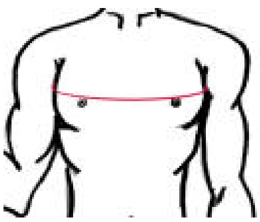

**Figure 4:** Tape position for measurement of mesosternale.

### 6.6.2. TEMPERATURE

Aural temperature and environmental temperature were measured throughout the test. Core temperature has been shown to have significant correlation to changes in heart rate (Buresh, Berg & Noble, 2005). It is thought that both the graduated compression garments and the placebo garments could effect body temperature due to the amount of skin surface area covered by the garments (Bringard, Perry & Bulluye, 2005; Shim et al, 2001). It has been claimed that compression garments can aid performance by increasing muscle temperature to optimal levels (Doan et al, 2003; Shim et al, 2001) but also preventing over heating which would lead to decreases in performance (Oksa, Rintamäki & Rissanen, 1997; Ferretti et al 1991; Wade et al, 2000).

**Aural temperature**

Aural temperature was measured using an infra red thermometer from the right ear (Welch Allyn Braun Thermscan Pro 4000, Bodycare, UK). The probe was positioned within the ear canal in accordance with the manufacturer's guidelines. The helix of the ear was pulled upwards and backwards and the probe inserted into the ear canal, and remained in situ for 10 seconds prior to measurement being taken.

**Environmental temperature and humidity**

Environmental temperature and humidity data was collected using a multi channel Oregon Scientific thermometer and hygrometer (Oregon Scientific Ltd. Model: BAR688HG, www.oregonscientific.com). The main unit was positioned indoors ensuring it was in view of the outdoor remote sensor. The outdoor remote sensor was positioned out of direct sunlight and moisture, facing the main indoor unit, with no obstructions between the two devices.

### 6.6.3. TOTAL BODY SWEATING

Total body sweating was assessed using pre- and post-test nude body weight (Pimental, Cosimini, Sawka, & Wenger, 1987; Harrison, Edwards & Leitch, 1975). This was measured as the graduated compression garments claim to have wicking properties which draw the sweat off the body and release it into the environment, thus aiding temperature regulation (www.skins.com.au).

### 6.6.4. Heart Rate

Heart rate was monitored continuously throughout testing using a Polar Vantage 810™ monitor. A pre-reading was taken in thermal neutral conditions in order to establish a true resting heart rate for each subject. Heart rate will be analysed as a measure of work rate for each of the tests (Desgorces et al, 2007).

### 6.6.5. Blood Lactate

Compression garments have been shown to promote lactate removal through improved blood flow around the body initiated by an increase in venous return (Chatard et al, 2004; Gill, Beaven & Cook, 2006). Lactate can also be used as a measure of work rate (Desgorces et al, 2007).

Approximately 5µl of capillary blood was taken using a finger prick from a warmed, sterilized, dry finger. The blood was then analysed enzymatically for 60secs using a semi-automated Lactate Pro Test Meter (Arkray Inc., Kyoto, Japan).

Following each lactate sample the Softclix Pro lancing device was disposed of using a Guardian Nestable sharps collector (Becton & Dickinson Ref no. 300421. Size 7.6 litre). All other contaminated materials, gloves, cotton wool, alcohol wipes, were disposed of using hazardous waste bags. The Guardian Nestable sharps collector and hazardous waste bags were then returned to the University of Chester for incineration.

### 6.6.6. Rating of perceived exertion (RPE) (Borg, 1982)

Subjective ratings of perceived exertion were taken throughout the testing protocol using Borg's RPE scale and instructions can be seen in appendix 14. RPE was taken as a measure of work rate and exertion level (Desgorces et al, 2007).

### 6.6.7. Subjective ratings.

Other subjective ratings taken throughout the protocol were:

**Perception of clothing sweating sensation** (Bringard, Perry & Bulluye, 2006; Gavin et al, 2001).

**Clothing comfort sensation** (Bringard, Perry & Bulluye, 2006; Ha, Tokura, Tanaka & Holmer, 1996).

**Whole thermal sensation** (Bringard, Perry & Bulluye, 2006; Ha et al, 1996).

(See appendices 15, 16 and 17 respectively).

The origins of these subjective scales are unsure. Therefore the inclusion of these scales as measures in this study was on the basis of previous published research which had included these as measures.

### 6.7. Statistical analysis

All data collected during the test protocol was inputted into Microsoft Office Excel where group means were generated in order to carry out statistical analysis. SPSS version 14.0 was used to make all statistical analyses. Analysis of parametric data consisted of a One-Way repeated measures ANOVA to determine if there was significant differences in the performances and physiological responses during the test protocol. All data was tested to ensure it was normally distributed and the Homogeneity of variance test was non-significant (Field, 2005, p.238). If the result of the One-Way repeated measures ANOVA indicated a significant difference between groups, the paired t-test was performed to identify where the differences lay. The level of statistical significance was set at $p = 0.05$. The Bonferonni adjustment was used because of multiple comparisons, to avoid the risk of committing a Type I error.

Statistical analysis of non-parametric data consisted of the Friedman's One-Way ANOVA, as this is the non-parametric equivalent of the One-Way repeated measures ANOVA (Huck, 2000, p.667). Providing there was a significant difference between the test conditions, the non-parametric post-hoc test consisted of the Wilcoxon matched-pairs signed-ranks test to highlight where the differences lay. As this test made all possible pairwise comparisons the Bonferroni adjustment was made to the significance level to avoid the risk of committing a Type I error (Huck, 2000, p.668).

All SPSS outputs can be seen in appendix 18.

# CHAPTER 3

# RESULTS

Out of the 23 possible participants making up the Telford and Wrekin Hockey Club registered National League squad, three did not meet the criteria as they were goalkeepers, three ruled themselves out prior to enrolment in the study due to injury, and the services of the final three were not needed due to the requirement of 14 participants being met. All participants starting the test completed the required two familiarisation sessions and three testing sessions. There were no injuries picked up by the participants during the test protocol and none dropped out, even though participants were free to do so at any time. The mean age of participants in this study was 24 ± 4 years. Participants mean height, weight and chest size were 177.6 ± 5.3 cm, 73.6 ± 7.1 kg, and 92.1 ± 5.6 cm respectively.

Testing took place during the hockey season between the 3rd March 2008 and the 1st May 2008. The mean number of days between participants completing the first testing session and third testing session was 14 ± 7 days. The mean time of day testing sessions took place was 1500 hours ± 1 hour. Mean temperatures during the three testing sessions were 11.6 ± 2.9 ºC, 10.4 ± 4.3 ºC and 8.9 ± 3.3 ºC and were not significantly different (chi-square = 4.429; p = 0.109). Mean humidity during the three testing sessions was 63 ± 12%, 64 ± 15% and 63 ± 10% and were not significantly different (chi-square = 0.444; p = 0.801).

## 7. DATA ANALYSIS

Prior to statistical analysis taking place group means were calculated, which can be seen in table 2 below.

**Table 2**: Group means for test variables.

| Test | | Control | Placebo | Graduated compression garments |
|---|---|---|---|---|
| Skill test mean total time (seconds) | Pre | 102.61 ± 8.02 | 103.72 ± 7.40 | 102.71 ± 6.43 |
| | Post | 101.66 ± 6.94 | 102.95 ± 8.19 | 102.18 ± 6.45 |
| Repeated sprint test Fatigue time (seconds) | Pre | 0.59 ± 0.38 | 0.54 ± 0.18 | 0.72 ± 0.35 |
| | Post | 0.65 ± 0.33 | 0.47 ± 0.19 | 0.54 ± 0.31 |
| Intermittent endurance test mean distance (metres) | | 1699.92 ± 120.19 | 1682.07 ± 155.48 | 1767.71 ± 140.45 |
| Heart Rate (bpm) | | 126 ± 8 | 125 ± 10 | 127 ± 8 |
| Blood Lactate (mMol/l) | | 6.13 ± 2.01 | 6.12 ± 2.31 | 6.30 ± 2.30 |
| Core Temperature (ºC) | | 36.4 ± 0.4 | 36.5 ± 0.5 | 36.4 ± 0.5 |
| Whole Thermal rating | | 2.86 ± 0.77 | 2.89 ± 0.68 | 2.93 ±0.51 |
| Clothing Comfort ratings | | 2.5 ± 1.09 | 3.0 ± 1.36 | 1.0 ± 0.76 |
| RPE | | 11.99 ± 1.04 | 11.86 ± 1.28 | 11.78 ± 1.19 |

## 7.1. PERFORMANCE DATA

### 7.1.1. Hockey skill test

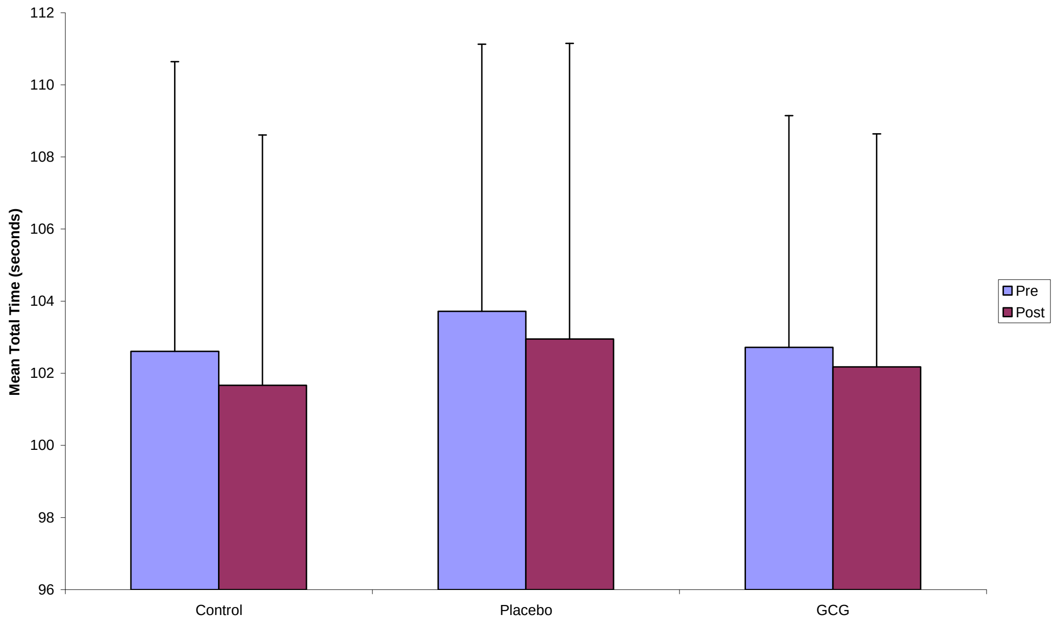


**Figure 5:** Bar chart showing total skill test times pre and post intermittent endurance test.

Mean results of the total skill test times pre intermittent endurance test were 102.61 ± 8.02s, 103.72 ± 7.40s, and 102.71 ± 6.43s for control, placebo and graduated compression garments respectively. Post intermittent endurance test scores were 101.66 ± 6.94s, 102.95 ± 8.19s, and 102.18 ± 6.45s for control, placebo and graduated compression garments respectively (see figure 5). There was no significant difference between clothing conditions, $f = 0.225$; $p = 0.800$ and $f = 0.198$; $p = 0.822$ for pre and post test scores respectively.

A paired samples t-test was carried out on total skill time to find out if there was any difference pre and post intermittent endurance test within clothing conditions. Time differences between pre and post results were 0.95s, 0.77s and 0.53s for control, placebo and graduated compression garments respectively. Results show no significant differences within clothing conditions $t = 0.602$; $p = 0.557$, $t = 0.351$; $p = 0.731$, and $t = 0.272$; $p = 0.790$ for control, placebo and graduated compression garments respectively.

The hockey skill test comprised of a number of components, namely the dribble, decision making, recovery and penalties (see table 3). Statistical analysis of the hockey skill test components showed no significant difference between clothing conditions for any of the hockey skill components pre intermittent endurance test (dribble $f = 0.198$; $p = 0.822$, decision making chi-square = 1.1714; $p = 0.424$, recovery $f = 0.270$; $p = 0.766$, penalties Chi-square = 0.727; $p = 0.695$).

**Table 3:** Results of the hockey skill test components.

| Skill test component | Pre/Post Intermittent endurance test. | Control | Placebo | GCG | Significance |
|---|---|---|---|---|---|
| | | Mean time (seconds) | | | |
| Dribble | Pre | 6.87 ± 0.45 | 6.82 ± 0.47 | 6.88 ± 0.40 | p = 0.822 |
| | Post | 6.92 ± 0.49 | 6.91 ± 0.51 | 6.97 ± 0.51 | p = 0.843 |
| Decision | Pre | 4.36 ± 0.44 | 4.57 ± 0.54 | 4.49 ± 0.58 | p = 0.424 |
| | Post | 4.34 ± 0.41 | 4.48 ± 0.48 | 4.41 ± 0.36 | p = 0.444 |
| Recovery | Pre | 5.05 ± 0.78 | 5.05 ± 0.68 | 4.96 ± 0.74 | p = 0.766 |
| | Post | 4.96 ± 0.73 | 4.96 ± 0.53 | 4.87 ± 0.61 | p = 0.701 |
| Penalties | Pre | 0.80 ± 0.53 | 0.83 ± 0.67 | 0.78 ± 0.67 | P = 0.695 |
| | Post | 0.71 ± 0.74 | 0.78 ± 0.79 | 0.76 ± 0.59 | p = 0.684 |

Analysis, post intermittent endurance test, again showed no significant difference between clothing conditions for any of the hockey skill components (dribble f = 0.172; p = 0.843, decision making f = 0.838; p = 0.444, recovery f = 0.360; p = 0.701, penalties chi-square = 0.760; p = 0.684) (see table 3).

### 7.1.2. Repeated sprint ability

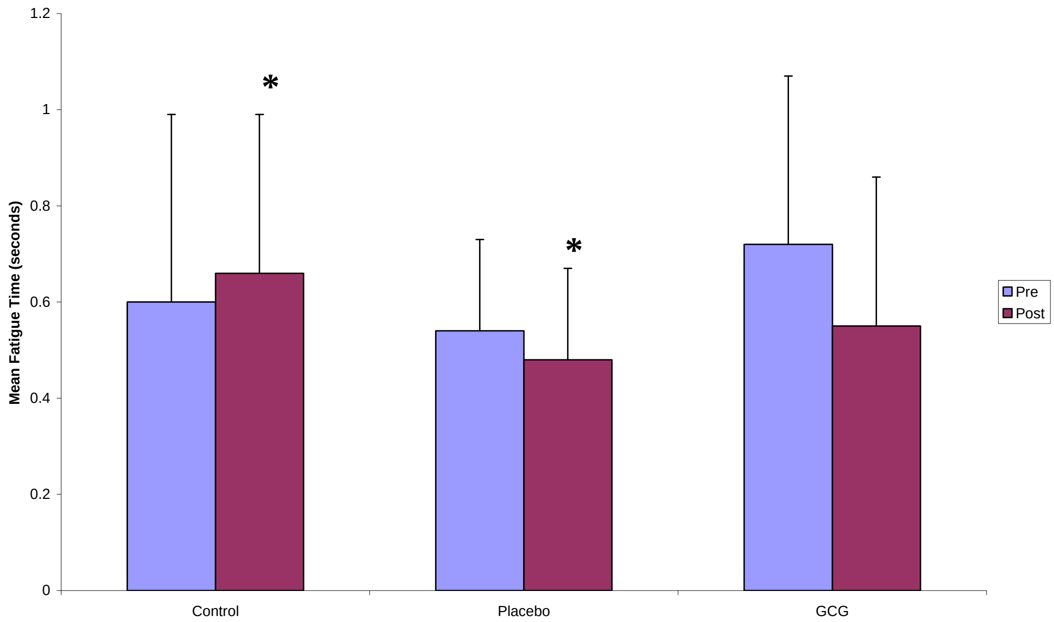


**Figure 6:** Bar chart showing the fatigue time for repeated sprint ability pre and post intermittent endurance run. (* significant difference between control and placebo post fatigue time).

Results of the repeated sprint ability test, pre intermittent endurance test, showed no significant difference between clothing conditions as regards to fatigue time (Chi-square = 1.000; p =

0.607), fastest sprint (f = 0.485; p = 0.558), slowest sprint (f = 0.359; p = 0.618), and mean sprint time (f = 0.173; p = 0.764) (see figure 6 and table 4).

**Table 4:** Results of the repeated sprint ability test.

| Sprint test component | Pre/Post intermittent endurance test | Control | Placebo | GCG | Significance |
|---|---|---|---|---|---|
| | | Mean time (seconds) | | | |
| Fatigue time | Pre | 0.59 ± 0.38 | 0.54 ± 0.18 | 0.72 ± 0.35 | p = 0.607 |
| | Post | 0.65 ± 0.33* | 0.47 ± 0.19* | 0.54 ± 0.31 | P = 0.011 |
| Fastest sprint | Pre | 7.28 ± 0.35 | 7.33 ± 0.34 | 7.24 ± 0.31 | p = 0.558 |
| | Post | 7.47 ± 0.29 | 7.54 ± 0.46 | 7.60 ± 0.45 | P = 0.404 |
| Slowest sprint | Pre | 7.88 ± 0.33 | 7.87 ± 0.39 | 7.79 ± 0.55 | p = 0.618 |
| | Post | 8.12 ± 0.38 | 8.02 ± 0.49 | 8.14 ± 0.62 | P = 0.319 |
| Mean sprint | Pre | 7.62 ± 0.27 | 7.62 ± 0.38 | 7.58 ± 0.37 | p = 0.764 |
| | Post | 7.84 ± 0.31 | 7.78 ± 0.48 | 7.83 ± 0.48 | P = 0.859 |

Results of the repeated sprint ability test, post intermittent endurance test, showed significant difference between clothing conditions as regards to fatigue time (see figure 6 and table 4). The Friedmans ANOVA statistic highlights significant difference between clothing conditions Chi-square = 8.982; p = 0.011. Wilcoxon matched pairs statistic indicates significant difference between control and placebo (Z = -2.828; p = 0.005), but no significant difference between control and graduated compression garments (Z = -1.790; p = 0.073), and between graduated compression garments and placebo (Z = -0.314; p = 0.753).

All other repeated sprint ability data, post intermittent endurance, was not significantly different, fastest sprint (chi-square = 1.815; p = 0.404), slowest sprint (Chi-square = 2.286; p = 0.319), and mean sprint time (f = 0.153; p = 0.859) (see table 2).

### 7.1.3. Intermittent endurance

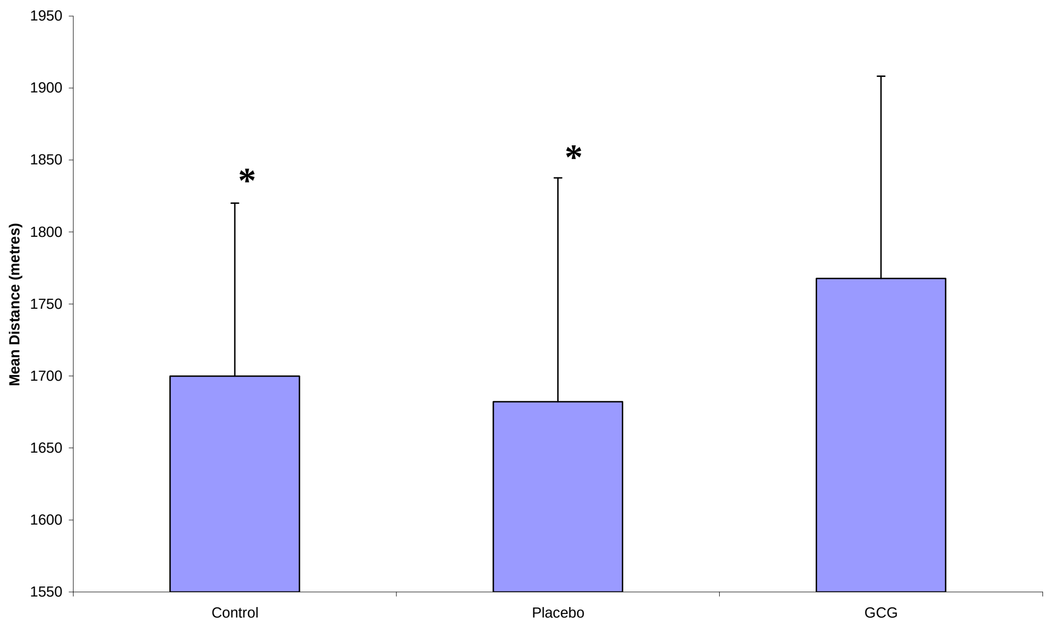


**Figure 7:** Bar chart showing the results of the intermittent endurance test. (* significant difference to graduated compression garments).

The mean distances covered by participants during the intermittent endurance test were 1699.92 ± 120.19m, 1682.07 ± 155.48m, and 1767.71 ± 140.45m for control, placebo and graduated compression garments respectively (see figure 7). Analysis of the intermittent endurance test data indicated there to be significant differences between clothing conditions ($f = 13.086$, $p < 0.0005$). Pairwise comparisons were made between the 3 clothing conditions to find out where the significant differences lay. Results show significant difference between control and graduated compression garments ($p = 0.002$) and between placebo and graduated compression garments ($p = 0.002$). There was no significant difference between control and placebo ($p > 0.05$).

## 7.2. PHYSIOLOGICAL DATA

### 7.2.1. Heart Rate

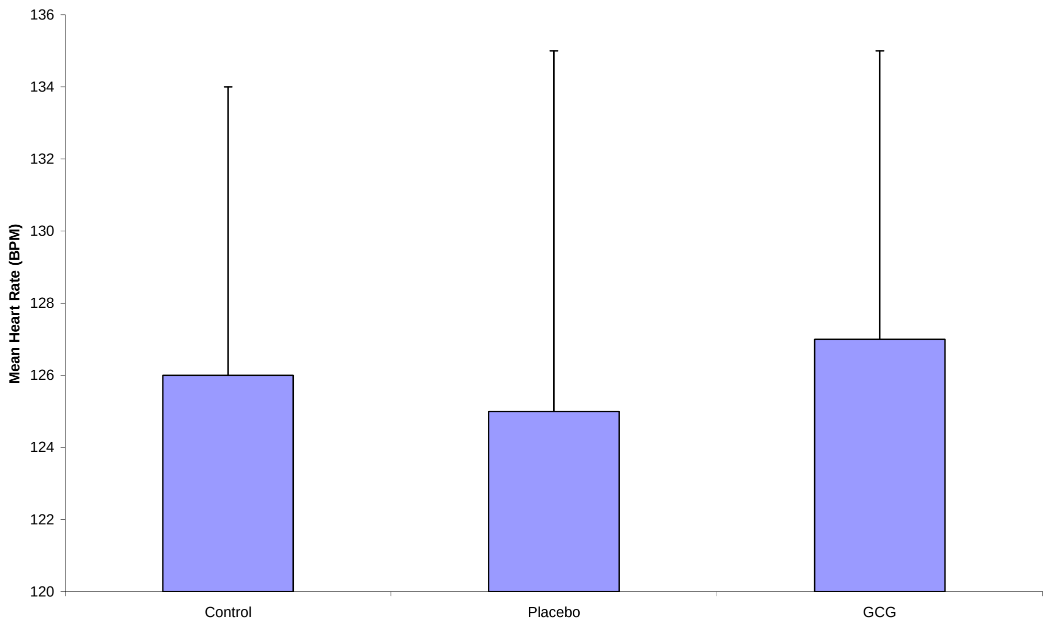


**Figure 8:** Bar chart showing mean heart rates for the whole test protocol.

Mean heart rates for the whole test protocols were 126 ± 8 bpm (beats per minute), 125 ± 10 BPM, and 127 ± 8 BPM, for control, placebo and graduated compression garments respectively (see figure 8). Mean heart rates were not significantly different between clothing conditions (f = 0.691, p = 0.510).

### 7.2.2. Blood Lactate

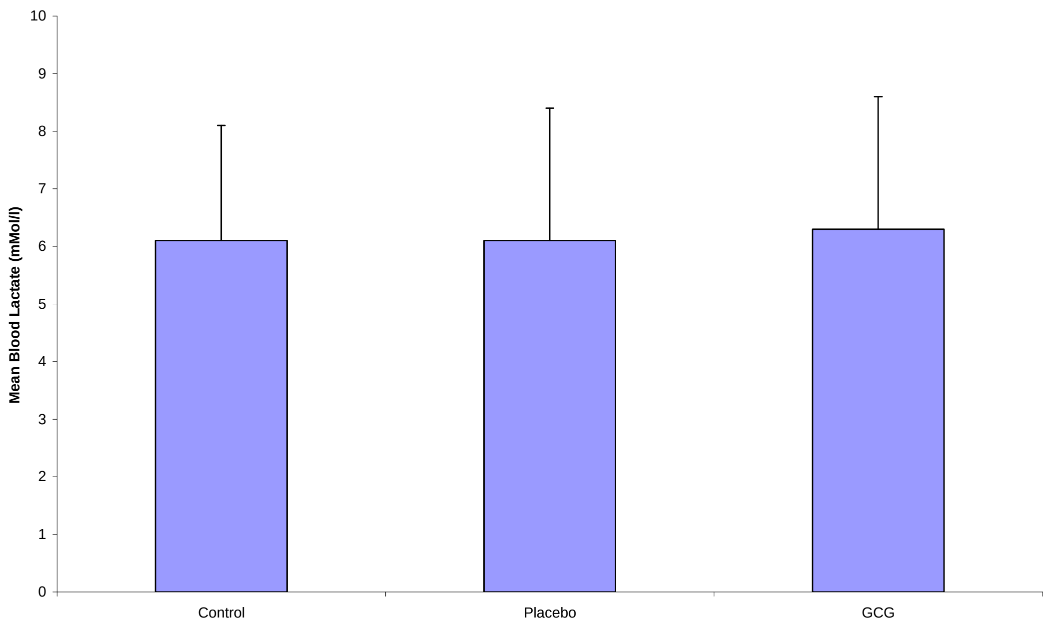


**Figure 9:** Bar chart showing blood lactate levels for the whole test protocol.

Mean lactate levels (6.13 ± 2.01 mMol/l, 6.12 ± 2.31 mMol/l, and 6.30 ± 2.30 mMol/l for control, placebo and graduated compression garments respectively) for the whole test protocol were not significantly different between clothing conditions ($f = 0.113$, $p = 0.893$) (see figure 9).

### 7.2.3. Core Temperature

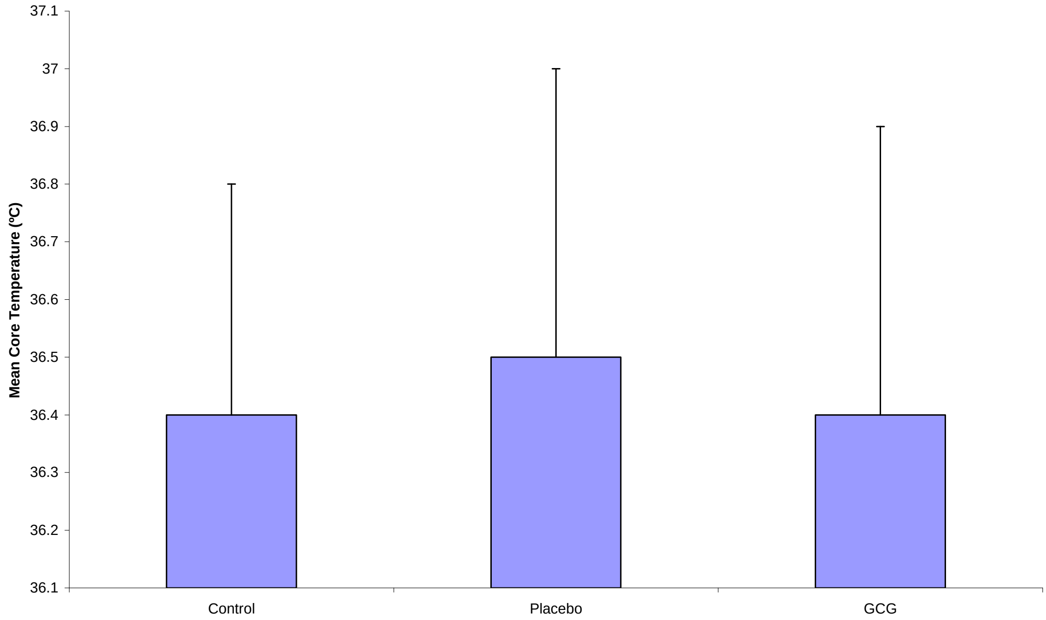


**Figure 10:** Bar chart showing mean core temperatures for the whole test protocol.

Mean core temperatures between clothing conditions were 36.4 ± 0.4 ºC, 36.5 ± 0.5 ºC, and 36.4 ± 0.5 ºC for control, placebo and graduated compression garments respectively (see figure 10). Therefore core temperatures were not significantly different between clothing conditions ($f = 0.708$, $p = 0.502$).

## 7.3. SUBJECTIVE DATA

### 7.3.1. Whole Thermal

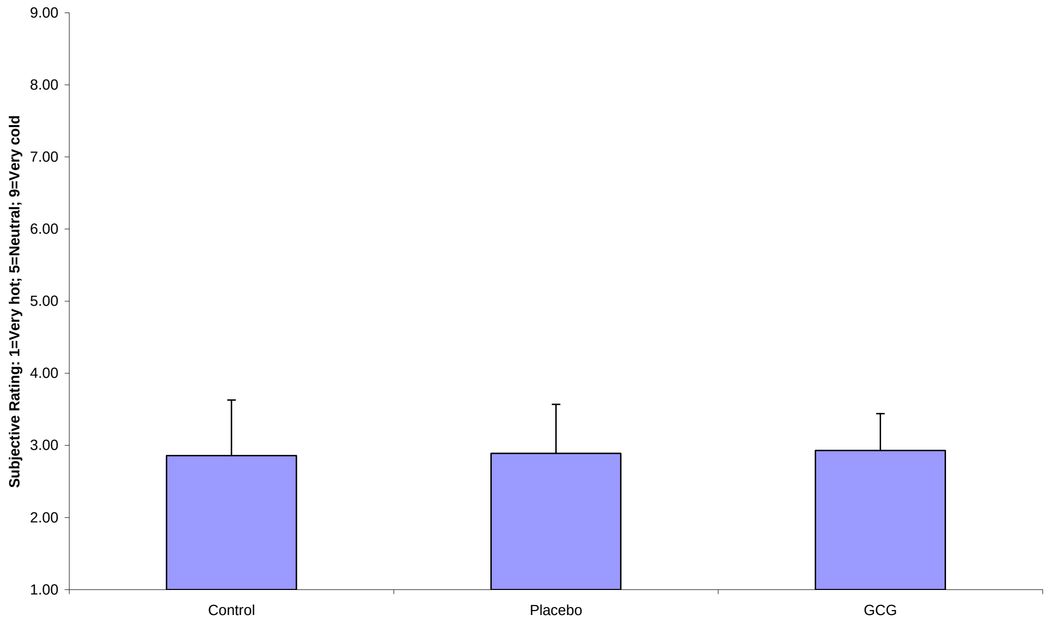


**Figure 11:** Bar chart showing subjective ratings of whole thermal sensation for the whole test protocol.

Subjective scores of whole thermal ratings were 2.86 ± 0.77, 2.89 ± 0.68 and 2.93 ± 0.51 for control, placebo and graduated compression garments respectively (see figure 11). No statistical significance was found between clothing conditions (Chi-Square = 0.486; $p = 0.784$).

### 7.3.2. Clothing Sweating Sensation

Results of subjective ratings for clothing sweating sensations highlighted no significant difference between clothing conditions during all test protocol components pre intermittent endurance test and also on completion of the intermittent endurance test. However, at all test protocol components post intermittent endurance test, subjective rating of clothing sweating sensation were found to be significant between clothing conditions (see table 5).

**Table 5:** Mean subjective ratings for clothing sweating sensation.

| Protocol component | Control | Placebo | GCG | Significance |
|---|---|---|---|---|
| | Mean (subjective ratings) | | | |
| Skill post | 3.71 ± 0.61 | 3.50 ± 0.94 | 2.86 ± 0.86* | $p = 0.015$ |
| Sprint post | 4.00 ± 0.55 | 3.43 ± 0.94 | 3.00 ± 0.96* | $p = 0.001$ |
| Recovery | 2.20 ± 0.62 | 2.50 ± 0.93 | 1.80 ± 0.57* | $p = 0.0014$ |

**Skill post intermittent endurance test**

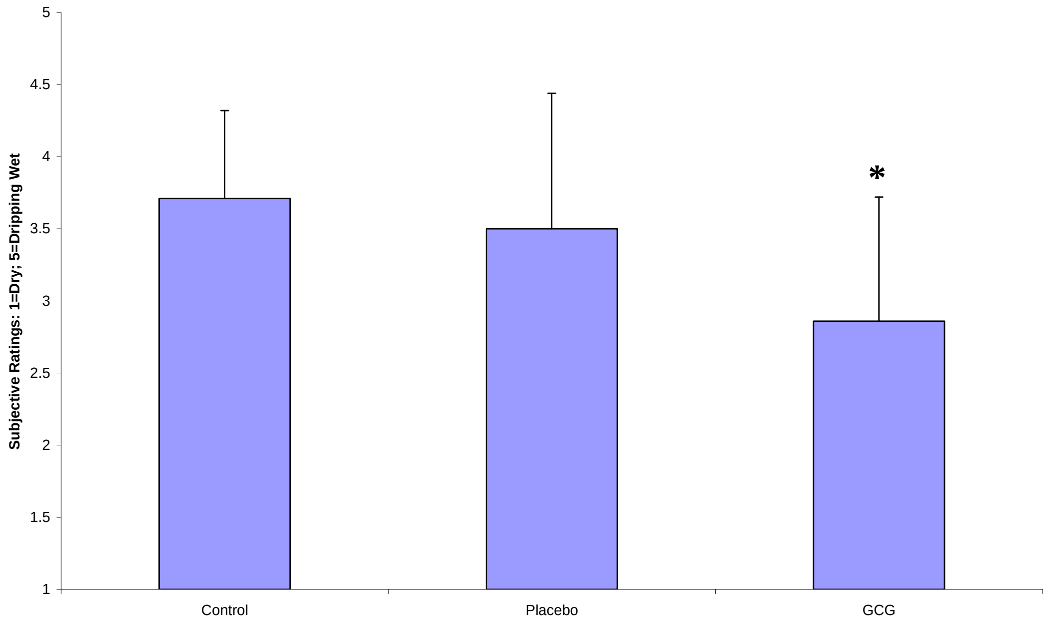


**Figure 12:** Bar chart showing subjective ratings of clothing sweating sensation at skill post intermittent endurance test. (* significantly different to control and placebo).

Subjective ratings of clothing sweating sensation were found to be significant at skill test post endurance (Chi-square = 8.359; p = 0.015), see figure 12, and table 5 for mean scores.

Wilcoxon matched pairs statistic shows, for skill post endurance, there to be significant difference between control and graduated compression garments (Z = -2.521; p = 0.012), but no significant difference between control and placebo (Z = -1.134; p = 0.257), and between placebo and graduated compression garments (Z = -1.998; p = 0.046).

## Sprint Post intermittent endurance test

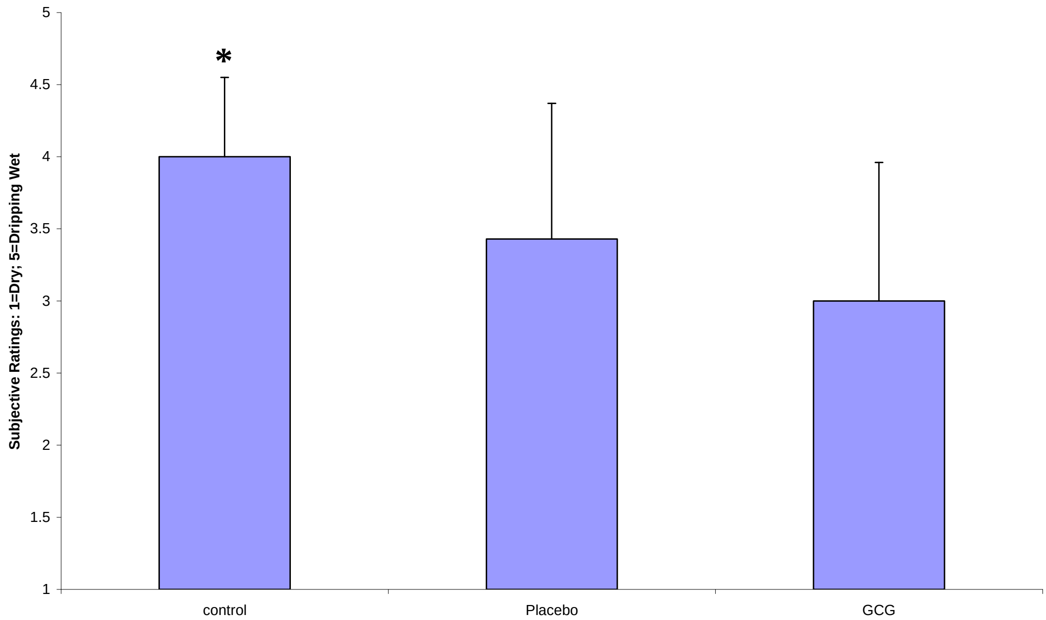


**Figure 13:** Bar chart showing subjective ratings of clothing sweating sensation at repeated sprint ability test post intermittent endurance test. (* significant difference between control and graduated compression garments).

Subjective ratings of clothing sweating sensation were significantly different at sprint test post endurance (Chi-square = 14.974; $p = 0.001$), see table 5 for mean scores.

Wilcoxon matched pairs results for the sprint test post endurance show a significant difference between control and graduated compression garments ($Z = -3.071$; $p = 0.002$), but no significant difference between control and placebo ($Z = -2.309$; $p = 0.021$), and between placebo and graduated compression garments ($Z = -1.897$; $p = 0.058$).

## Recovery

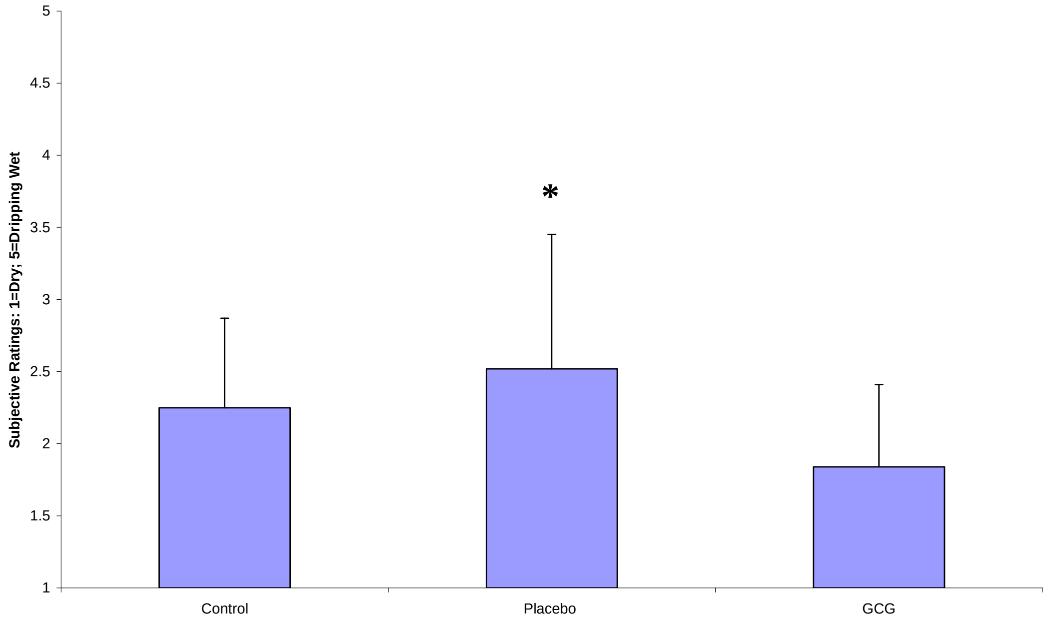


**Figure 14:** Bar chart showing subjective ratings of clothing sweating sensation for recovery. (* significant difference between placebo and graduated compression garments).

Subjective ratings of clothing sweating sensation were significantly different between clothing conditions during recovery (Chi-square = 8.510; p = 0.0014), see table 5 for mean scores.

Wilcoxon matched pairs results for the 20 minute recovery period show significant difference between placebo and graduated compression garments (Z = -2.606; p = 0.009), but no significant difference between control and placebo (Z = -0.983; p = 0.326) and between control and graduated compression garments (Z = -2.014; p = 0.044).

### 7.3.3. Clothing Comfort Sensation

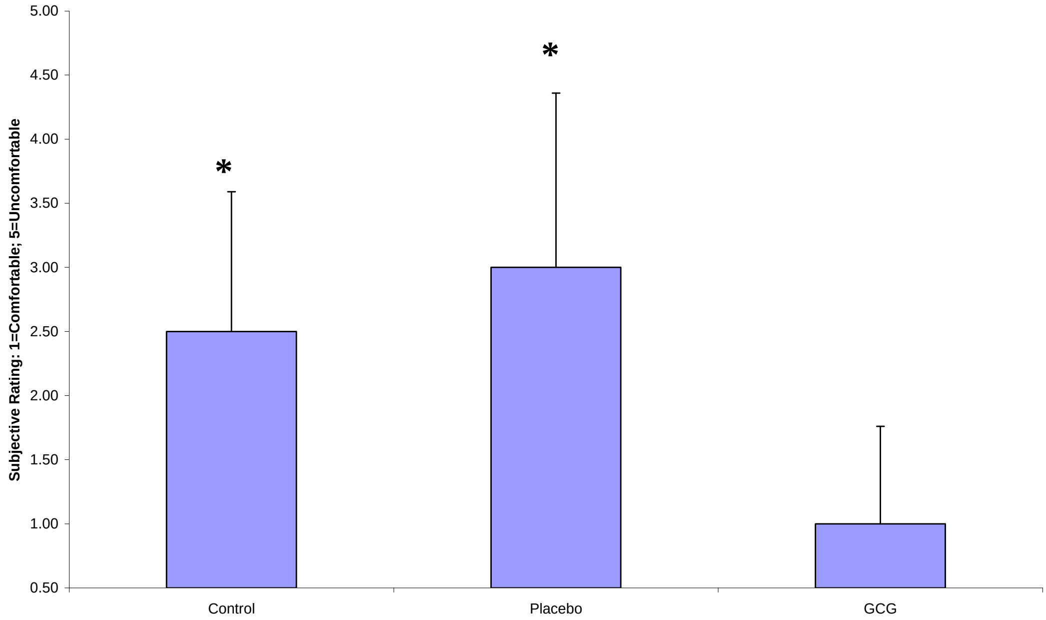


**Figure 15:** Bar chart showing subjective ratings of clothing comfort sensation for the whole test protocol. (* significantly different to graduated compression garments).

Mean clothing comfort ratings for the entire test period were 2.5 ± 1.09, 3.0 ± 1.36 and 1.0 ± 0.76 for control, placebo and graduated compression garments respectively (see figure 15). Clothing comfort sensation was found to be significantly different between clothing conditions using the Friedman's ANOVA statistic (Chi-Square = 8.341; p = 0.015). Post-hoc tests indicate there to be significant difference between control and graduated compression garments (Z = -2.511; p = 0.012) and between placebo and graduated compression garments (Z = -2.509; p = 0.012). There was no significant difference between control and placebo (Z = -1.492; p = 0.136).

### 7.3.4. RPE

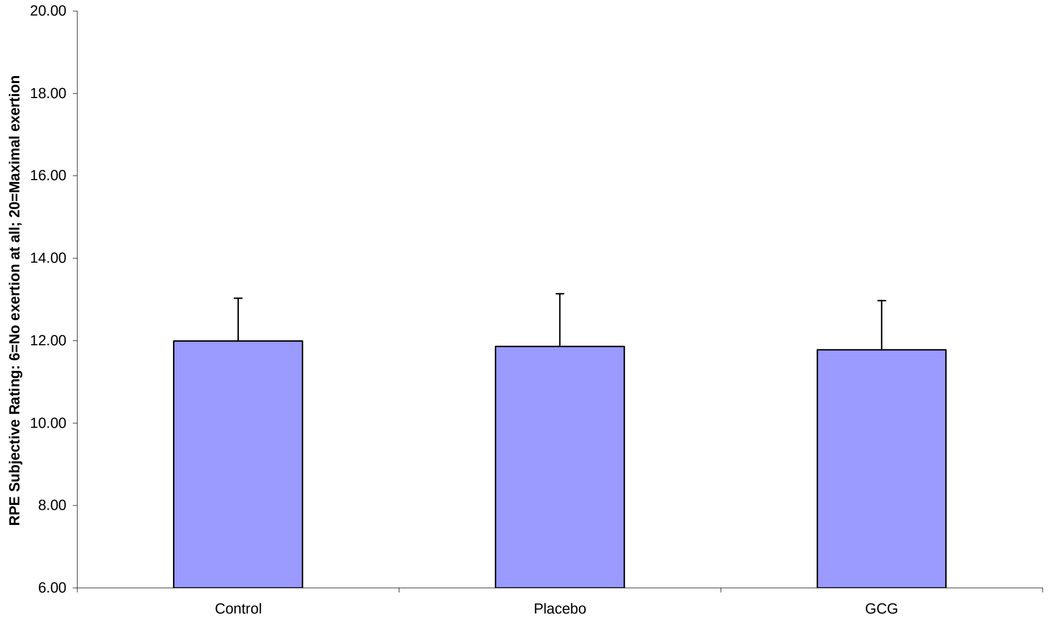


**Figure 16:** Bar chart showing subjective RPE ratings for the whole test protocol.

Mean subjective RPE ratings during the test protocol were 11.99 ± 1.04, 11.86 ± 1.28 and 11.78 ± 1.19 for control, placebo and graduated compression garments respectively (see figure 16). There was no significant difference between clothing conditions (Chi-Square =1.623; p = 0.444).

# CHAPTER 4

# DISCUSSION

### 8.1. Field-Hockey skill

Null Hypothesis 1: “Graduated compression garments do not significantly improve field-hockey skill performance following an intermittent endurance test”.

Results of the hockey skill test show that the wearing of graduated compression garments did not lead to any direct improvement in field-hockey skill performance, as indicated by the pre intermittent endurance results. By doing the skill test first on the test protocol, participants would be under the least amount of physiological and psychological fatigue, thus giving the best possible chance of highlighting any direct skill improvements which could be attributed to graduated compression garments.

Results of the hockey skill test post intermittent endurance test again showed no significant difference between clothing conditions. Therefore on this basis the Null Hypothesis 1 can not be rejected, “Graduated compression garments do not significantly improve field-hockey skill performance following an intermittent endurance test”.

It is to this researcher’s knowledge that this is the first study to test the effects of graduated compression garments on field-hockey skill performance. Therefore comparisons of the present results are problematic. Results of Sunderland et at (2006), who designed the hockey skill test, report lower test times than were recorded in the present study. They report mean times for males (n = 20) as 83.93 ± 6.60 seconds in the initial trial and 84.36 ± 7.44 seconds in the second trial. The results of the skill test in the present study were 102.61 ± 8.02 seconds, 103.72 ± 7.40 seconds and 102.71 ± 6.43 seconds for control, placebo and graduated compression garments respectively. That is approximately 20 seconds difference in time scores between the two studies. Some possible explanations for these differences are firstly the surface on which the tests were performed. Sunderland et al (2006) performed their test on a water-based sportsturf (Desso), which are generally slicker than the sand based astro-turf pitch used in the present study. Secondly the test was performed at Loughborough University, therefore the sample population could potentially be playing in the top tier of National League hockey in the country. The participants in the present study were third tier hockey players at the time of testing (National League North). This begs the question of whether benefits of compression garments on skill performance may be more apparent at the elite end of the hockey scale.

It is suggested by certain manufacturers (Skins™, Canterburt, BSc) of compression garments that their products may improve skill as a result of improved proprioception. This theory of improved proprioception has also been stated by a number of researchers (Bringard, Perry & Bulluye, 2006; Doan et al, 2003) as a possible contributing factor to improvements in performance shown in their studies regarding compression garments. However, this is more through speculation rather than quantitative evidence. Perlau, Frank and Fick (1995) demonstrated improvements in knee proprioception with elastic bandages, but whether this directly crosses over into a sporting context, regarding skill, with compression garments, is not really known. Skill is said to be the learned ability to bring about pre-determined results with maximal certainty, often with the minimum outlay of energy, or of time and energy (Knapp, 1963). As the present study had no way of measuring proprioception, the quantification of skill was through time, and as the results point out graduated compression garments did not significant reduce time taken to perform the hockey skill test.

If the results of the intermittent endurance test are taken into account, i.e. graduated compression garments resulted in significant improvements over control and placebo, it may be claimed that graduated compression garments help to maintain field-hockey skill performance whilst significantly improving intermittent endurance.

### 8.2. Repeated sprint ability

Null Hypothesis 2: “Graduated compression garments do not significantly improve repeated sprint ability following an intermittent endurance test”.

Results for repeated sprint ability pre intermittent endurance test showed no significant difference between clothing conditions for fatigue time, fastest sprint, slowest sprint and mean sprint time.

This was the same trend for post intermittent endurance results, with the exception of fatigue time which was found to be significantly different between placebo and control. On this basis the Null Hypothesis 2 can not be rejected, “Graduated compression garments do not significantly improve repeated sprint ability following an intermittent endurance test”.

Previous research on compression garments and power output have shown positive significant results (Doan et al, 2003; Lambert, 2005b; Shim et al, 2001), although these studies tested power output in terms of squatting power, leg press or jumping power. This study aimed to test the power output of graduated compression garments in terms of sprinting speed, and repeated sprint ability to assess the reduced fatigue effect on power output demonstrated in these previous studies.

Argus (2005) found graduated compression garments to significantly improve repeated sprint ability, in terms of mean sprint time, over three consecutive days and then four days after this. But as these improvements did not become apparent until the next day this may point to possible long duration recovery benefits of compression garments.

The repeated sprint ability test protocol used in the pilot study by Higgins (2004) is very similar to that used in the present study. Their sprint protocol consisted of seven straight line sprints, each lasting seven seconds, with a 23 second passive recovery between each sprint. Their study measured the distance covered by participants in each seven second sprint. Mean distance results were 48.20 ± 2.06 metres and 48.42 ± 2.46 metres for control and graduated compression garments respectively. The mean drop off distances were 7.09 ± 2.76 metres and 5.38 ± 0.92 metres for control and graduated compression garments respectively. It is obvious that there is not much difference between the mean distances covered, but when the drop off distances are compared it looks like graduated compression garments are in fact showing a positive effect. However the Independent t Test for average drop off distance showed a T-ratio (n-1) of 1.36 and this was not significant when the alpha level of 0.10 (1.943) was applied. The lack of significance in this study is thought to be down to the low number of participants (n = 4). The results of the present study showed no significant differences in fatigue drop off times pre intermittent endurance test. Post intermittent endurance fatigue times showed a significant difference between control and placebo ($p = 0.005$), but no significant difference between graduated compression garments and placebo, and between graduated compression garments and control. An explanation for the significant placebo result is not known.

Therefore the results of the present study would support the previous research (Argus, 2005, Higgins, 2004) in that graduated compression garments do not show any direct significantly improvements repeated sprint ability.

This would support the studies by Kraemer et al, 1996; Lambert, 2005b; Kraemer, Bush, and Newton, 1997, who also were unable to highlight direct power gains in compression garments, but instead suggest benefits are more to do with a reduction in fatigue.

These possible reductions in fatigue associated with graduated compression garments may be demonstrated by the post intermittent endurance test results. Mean sprint times were not significantly different between clothing conditions. This may demonstrate a reduction in fatigue in the graduated compression garments condition, as participants were able to run significantly further in the intermittent endurance test than control and placebo conditions, and still produce sprint times which were not significantly different to control and placebo conditions.

The notion of reduced muscle vibration, associated with graduated compression garments, may explain why no significant power output gains are being demonstrated in research into compression garments. The research into the effects of vibration on muscle contraction is that vibration enhances strength and power over a short duration. This occurs by vibration stimulating involuntary muscle contraction, resulting in more muscle fibre recruitment than would occur in a voluntary muscle contraction (Sidhu, 2008; Issurin & Tenenbaum, 1999). Therefore the muscles are used more quickly and more efficiently, rendering them capable of producing more force (Tihanyi et al, 2007; Paradisis & Zacharogiannis, 2007; Lamont et al, 2006; Cormie et al, 2006; Bosco, Cardinale & Tsarpela, 1999; Bosco et al, 2000; Rittweger, Schiessl & Felsenberg, 2001; Rittweger et al, 2002; Abercromby et al, 2005; Amonette et al, 2005; Bosco et al, 1999). Therefore if graduated compression garments work to reduce vibration, this would in theory reduce the muscular power output. This trend however was not seen in this study, demonstrated by the non significant difference between mean sprint times and mean fastest sprint times of the control clothing condition compared to the graduated compression clothing and placebo clothing condition. This may suggest that some of the other benefits associated with wearing graduated compression garments, proprioception (Bringard, Perry & Belluye, 2006; Doan et al, 2003; Fusco & Bohm, 2002; Kraemer, Bush & Newton, 1997; Barrack et al, 1983), muscle co-ordination (Bringard, Perry & Belluye, 2006; Kuster et al, 1999), correct muscle alignment, technique (Perlau, Frank & Fick, 1995), may cancel out any possible negatives caused by reduced vibration on power output. However this can only be speculated.

### 8.3. Intermittent endurance

Null Hypothesis 3: “Graduated compression garments do not significantly improve intermittent endurance running”.

Results of the intermittent endurance test showed that participants wearing graduated compression clothing were able to run significantly further, compared to a control group and placebo group. When the mean distances are compared (1699.92m, 1682.07m and 1767.71m for control, placebo and Skins respectively), this equates to a significant 3.98% increase in performance for graduated compression garments over the control group ($p = 0.002$), a significant 5.09% increase for graduated compression garments over the placebo group ($p = 0.002$), and a 1.05% reduction in performance for the placebo group over the control group ($p > 0.05$). Therefore the Null Hypothesis 3 is rejected and a new one proposed “Graduated compression garments significantly improve intermittent endurance running”. As this intermittent endurance test was effectively only one quarter of a field-hockey match, these significant improvements demonstrated with graduated compression garments could equate to a significant practical advantage over an opponent during a real match.

Together with the fact that the physiological markers of performance (mean heart rates and lactate levels) were not significantly different between clothing conditions, the results of this study support some of the findings and theories of previous research. The results can not be directly compared as none of the other studies have used the intermittent endurance test used in the present study. These theories generally focus on graduated compression garments increasing the efficiency of various physiological processes, thus reducing the energy cost of performance.

First and foremost is increased blood circulation. Graduated compression garments are said to aid the body's circulatory system by increasing venous return to the heart; this in turn increases blood flow to the working muscles resulting in improved microcirculation at the muscle bed and increased deep tissue oxygenation (Agu, Baker & Seifalian, 2004; Bringard, Perrey, & Belluye, 2006; Lambert & Chow, 2004; Higgins, 2004; Fusco & Bohm, 2002; Kraemer et al, 1998). This increased blood flow would also reduce the amount of lactate build up which was demonstrated by the non-significant results of blood lactate between clothing conditions in this study. This trend was also shown in the study by Lambert and Chow (2004) who found for the same peak lactate and $\dot{V}O_2max$ values, time to exhaustion was significantly improved whilst wearing SportSkins™ graduated compression garments.

Other research which could explain the results of the intermittent endurance test suggests that improvements in performance are due to reduction in muscle vibration and muscle oscillation as a result of wearing graduated compression garments (Bringard, Perrey, & Belluye, 2006; Doan et al, 2003; Shim et al, 2001; Kraemer, Bush, & Newton, 1997). The vibrations experienced during the intermittent endurance test are a result of impact shocks experienced through the leg following the heel strike during each running stride (Cardinale & Wakeling, 2005). The use of graduated compression garments in the present study may have helped to reduce the vibrations caused by the impact of running, resulting in less muscle activation in order to dampen the vibrations. This may have reduced the energy cost of muscle contraction during the run, allowing participants to cover a significantly longer distance, whilst imposing no significant difference between clothing conditions for mean heart rate and blood lactate levels. However, muscle vibrations were not directly measured in the present study, so the theory of reduced muscle vibration with compression garments can only be speculated, based on the suggestions of previous research.

Another theory which may support the significant results found for intermittent endurance running is graduated compression garments support the muscle and maintain it in its correct contractile direction (Bringard, Perrey, & Belluye, 2006). This is thought to optimise neurotransmission and mechanisms at a molecular level (McComas, 1996), which may lead to increased efficiency of muscle contraction, thus reducing the energy cost of any given exercise.

The research by Higgins, Naughton and Burges (2007) is considered the closest body of research out there which this study can compare to in terms of intermittent endurance. They tested specific netball drills and movement patterns, which are intermittent in nature, interspersed with low intensity rest/jog/run periods, during four 15 minute circuits in order to replicate game like performance. They demonstrated a 20% improvement in the ability to cover a greater distance, at a higher intensity, whilst wearing graduated compression garments over a control condition of normal netball attire. They also demonstrated a 34% improvement from graduated compression garments compared to a placebo clothing condition. However these findings were not deemed significant ($p = 0.09$). The intermittent endurance test in the present study lasting 16.5 minutes is generally a quarter of a game of hockey (35 minutes each half). Therefore if the percentage improvements demonstrated in the present study are multiplied by four, this could potentially equate to a 15.92% increase for graduated compression garments over control, and a 20.36% increase for graduated compression garments over placebo, during an entire hockey match. With the percentage results of Higgins, Naughton and Burges (2007) being much higher than those demonstrated in the present study, and yet significance not being met, may be a result of the statistical methods adopted in their study. They used a general linear model, with a repeated measures design ($f = 2.074$ and $p = 0.09$ for the markers of fast travel using the Huynh-Feldt correction factor), as apposed to the repeated measures ANOVA used in the present study.

Nevertheless Higgins, Naughton and Burges (2007) highlighted benefits of graduated compression garments in terms of intermittent endurance, which have been supported by the significant results highlighted in the present study.

### 8.4. Heart rate

Null Hypothesis 4: “Graduated compression garments do not significantly reduce heart rates during exercise performance or recovery”.

Results of this study showed no significant difference ($p = 0.510$) between clothing conditions for mean heart rates, 126 ± 8 bpm, 125 ± 10 bpm and 127 ± 8 bpm for control, placebo and graduated compression garments respectively. Therefore the Null Hypothesis 4 can not be rejected, “Graduated compression garments do not significantly reduce heart rates during exercise performance or recovery”.

As no other studies have tested the effects of graduated compression garments on the heart rates of field-hockey players during the tests used in the present study, no direct comparisons can be made.

The results of this study do not support the results of Higgins, (2004), that compression garments reduced heart rate by 5 to 7% during repeated sprints. However, significance was not met in the study by Higgins (2004), possible due to the fact it was a pilot study consisting of only four participants.

The study by Bringard, Perry and Bulluye (2006) testing the energy cost of submaximal running found no significant difference between heart rates for clothing conditions of conventional shorts, elastic tights and compression tights (174.3 ± 3.5 bpm, 175.0 ± 3.2 and 175.1 ± 1.3 bpm respectively, at 15 minutes of constant heavy running), despite showing significant reductions ($p = 0.01$ and $p = 0.04$) in the energy cost of running. These results for heart rates are similar to that seen in the present study in that mean values are only separated by one beat between clothing conditions, despite showing significant improvements in intermittent endurance running.

This study supports the findings of other researchers (Duffield & Portus, 2007; Houghton, Dawson & Maloney, 2007; Berry et al, 1990) in that compression garments do not significantly affect heart rates, $p > 0.05$ in all cases.

### 8.5. Blood lactate

Null Hypothesis 5: "Graduated compression garments do not significantly reduce blood lactate concentrations during exercise and recovery".

Results of blood lactate concentrations for the present study were not significantly different ($p = 0.893$) between clothing conditions ($6.13 \pm 2.01$ mMol/l, $6.12 \pm 2.31$ mMol/l and $6.30 \pm 2.3$ mMol/l for control, placebo and graduated compression garments respectively). Therefore the Null Hypothesis 5 can not be rejected, "Graduated compression garments do not significantly reduce blood lactate concentrations during exercise and recovery".

Problems with some of the research regarding lactate removal during exercise are results have been inferred rather than directly tested. Bringard, Perry and Bulleye (2006) suggest a reduction in blood lactate whilst wearing compression garments in their study based on the results of a reduced $\dot{V}O_2$ slow component. This is based on the research by Casaburi et al (1987), and later supported by Gaesser and Poole (1996), who highlight the close relationship between the $\dot{V}O_2$ slow component and the amount of blood lactate in cross sectional studies.

The pilot study by Higgins 2004 suggests a reduction in blood lactate levels when wearing graduated compression garments based the reduced heart rate levels found in their study. This inference is based on the results of Kenefick, Mattern, Mahood and Quinn (2002) in that heart rate and lactate threshold are closely correlated.

A more recent study by Higgins, Naughton and Burgess (2007) found that there was no significant difference in blood lactate concentrations between wearing graduated compression tights, placebo tights and a control during a game specific circuit for netballers. They suggest that this may be due to the trained state of the participants in their study having an increased ability to shift blood lactate. Other reasons proposed which may explain the low blood lactate levels were low intensity of performance, low motivation, high efficiency in the skills of the participants, and the time delay between finishing an exercise and being able to take the blood sample.

The results of blood lactate concentrations in this present study, being non significantly different between clothing conditions, therefore support these previous findings by Higgins, Naughton and Burgess (2007).

The research into the effects of compression garments on recovery lactate is still not clear. An early study by Berry and McMurray (1987) stated that elastic compression stockings reduced blood lactate levels during a 30 - 60 minute recovery period following a bout of exhaustive exercise. It was suggested that this was a result of increased venous blood flow, resulting in a greater removal of lactate and oxidation. A more recent study by Berry and associates (1990) then suggests that in fact elastic tights do not significantly affect the post-exercise response of circulating blood lactate levels. Results of a study carried out by Balmoral Triathlon Club (2003) found that following 57km of road cycling blood lactate concentrations were significantly reduced by 37% at three minutes and 38% at twenty minutes post exercise. These recovery benefits for blood lactate were also highlighted in the study by Chatard et al (2004), demonstrating a 20% reduction in blood lactate during an 80 minute recovery period whilst wearing elastic compression stockings.

Other studies have been unable to show such dramatic results as these and suggest that the benefits of wearing compression garments during recovery are more to do with preventing muscle damage (DOMS) and also subjective perceptions of muscle damage/soreness (Ali, Caine & Snow, 2007; Trenell et al, 2006; Gill, Beavan & Cook, 2006; Connolly, Sayers & McHugh, 2003; Kraemer et al, 2001). But as no measures were in place to monitor muscle damage in the present study, no comments can be made regarding this area of recovery.

Although graduated compression garments were not able to reduce blood lactate levels during exercise and recovery in the present study, they did maintain blood lactate levels comparable to a control group and placebo group which both performed significantly less during an intermittent endurance test. There was also no elevation in lactate levels whilst wearing graduated compression garments in both hockey skill performance and repeated sprint ability post intermittent endurance test, despite having just run significantly further than the control and placebo groups.

## 8.6. Thermoregulation

Null Hypothesis 6: “Graduated compression garments do not provide significant thermoregulatory or comfort advantages during exercise and recovery”.

Results of the present study show core temperatures to be non-significantly different between clothing conditions ($p = 0.502$). This is supported by subjective whole thermal ratings which were also non-significantly different between clothing conditions ($p = 0.784$). Subjective clothing sweating sensations were significantly improved whilst wearing graduated compression garments at field hockey skill test post intermittent endurance test and repeated sprint test post intermittent endurance test ($p = 0.015$ and $p = 0.001$ respectively). Subjective clothing sweating sensations were also significantly improved whilst wearing graduated compression garments during recovery ($p = 0.0014$). Subjective clothing comfort sensations were significantly improved whilst wearing graduated compression garments, compared to control and placebo ($p = 0.012$ and $p = 0.012$ respectively). It is suggested that, as core temperature and subjective whole thermal ratings showed no negative effects from wearing graduated compression garments, and clothing sweating sensations and clothing comfort sensations showed positive significant benefits of wearing graduated compression garments, the Null Hypothesis 6 is rejected. Therefore a new Hypothesis 6 is proposed “Graduated compression garments provide significant thermoregulatory and comfort advantages during exercise and recovery”.

The results of the present study are in contrast to early research by Nielsen, Gavhed and Nilsson (1989) who claim that tight fitting clothing impedes convection heat loss during exercise by reducing air circulation across the skin surface. Whereas loose fitting clothing promotes air circulation and convection heat loss reducing sweat production. The present study also does not support the notion of reduced sweat production associated with loose clothing as sweating rates, measured by the difference between pre and post nude body weight, were 0.8kg, 0.7kg and 0.9 for control (loose fitting clothing), placebo and graduated compression garments respectively ($p > 0.05$).

The present study supports more recent research by Houghton, Dawson and Maloney (2007), Bringard, Perry and Bulluye (2006) and Gavin et al, (2001) in terms of thermoregulation as these studies report no significant difference in core temperature and body mass loss between clothing conditions.

The present study also failed to show any benefits in wearing compression garments in terms of warm up temperatures as shown by Doan et al (2003). They found a compression garment to reduce the time during warm up for muscles to obtain what is thought to be optimal temperature for performance (38.5ºC). Although, the compression garment used in that study was of a much thicker make up (75% closed cell neoprene and 25% butyl rubber) than the graduated compression garments used in the present study. Also skin temperatures were not monitored in the present study so full comparison between the two studies can not be made.

The results for subjective sweating sensations and clothing comfort sensations in the present study show significant differences between clothing conditions. This is in contrast to the results by Bringard, Perry and Bulluye (2006) and Gavin et al (2001) who found no significant difference in these subjective ratings. The present study found that participants perceived sweating sensations to be significantly less whilst wearing graduated compression garments, compared to the control clothing condition, at hockey skill test post intermittent endurance, repeated sprint ability test post intermittent endurance and during recovery. This may support the wicking properties claimed by the manufacturers of the graduated compression garments, drawing the sweat away from the body. The present study differed from the two above in that this was a field based study and the two above were laboratory based. Therefore the wind may have contributed more to the proposed wicking properties of the graduated compression garments, although the study be Gavin et al (2001) did provide a simulated wind. Wind speeds were not measured during the present study so direct comparisons can not be made.

The results of sweating sensations in the present study may have contributed to the significant clothing comfort sensation results for graduated compression garments, as participants complained of being hot, clammy and uncomfortable whilst wearing the placebo garments, although no subjective comments were documented during the study.

### 8.7. Ratings of Perceived Exertion

Null Hypothesis 7: “Graduated compression garments do not significantly influence ratings of perceived exertion during exercise and recovery”.

Results of the present study show no significant difference for RPE scores between graduated compression garments, placebo garments and control clothing conditions for exercise and recovery. Therefore the Null Hypothesis 7 can not be rejected, “Graduated compression garments do not significantly influence ratings of perceived exertion during exercise and recovery”.

This is in accordance with previous research by Higgins, Naughton and Burgess (2007), Houghton, Dawson and Maloney (2007) and Bringard, Perry and Bulluye (2006) who to found no significant difference for RPE scores between compression garments, placebo garments and control.

When the mean RPE scores for the present study are compared, 11.99 ± 1.04, 11.86 ± 1.28 and 11.78 ± 1.19 for control, placebo and graduated compression garments respectively, it shows that graduated compression garments are in fact showing a marginal positive effect on RPE. Although no significant results were obtained in the present study, it is suggested that the ability to run significantly further during an intermittent endurance test whilst wearing graduated compression garments, compared to placebo and control groups, and participants not perceiving their exertion to have increased, may be seen as a positive influence.

# LIMITATIONS OF THE STUDY

It is thought that the hockey skill test in this study, involving whole body movements, incorporating many different skills and techniques, may have been too complex and open in nature to quantify any possible proprioceptive benefits from graduated compression garments. Even with concentrating on only one section of the human body, proprioception is considered difficult to quantify as even slight variations in test procedure can lead to substantial errors in measurements (Szulc, Lewandowski & Marecki, 2001). It may be more beneficial to concentrate on one aspect such as the push at goal in the, case of the present study. This could possibly be tested in terms of accuracy regarding the shot, or in terms of force production.

The lack of difference in repeated sprint ability performance may have been due to a lack of motivation expressed by the participants. This lack of motivation amongst participant was also reported by Higgins, Naughton and Burgess (2007). It was evident in the present study that participant were pacing themselves as quite often the final sprint was faster than those before it. A similar trend was also evident in the skill test although not as prominent as the sprint test.

Testing was highly dependant on the weather. As a result, a total of 20 sessions were cancelled due to rain, snow, high winds and low temperatures. The electronic timing gates were not waterproof, therefore could not be used in the rain or snow. High winds blew the post over in the repeated sprint ability test and also the intermittent endurance test. Testing could not take place without the posts as this would have effected times/distance covered due to participants being able to cut corners during the tests. Low temperatures caused all electronic equipment to malfunction.

The environmental factors will always be considered as a limitation to any research which is field based. However this was considered an important aspect of the present study, so that graduated compression garments could be tested in the environment they are most likely to be used, i.e. not in a laboratory environment. Also testing could take place on an astro-turf surface which was hoped would be more representative for the results.

Skin temperature was not assessed during the study, so the true extent to how the graduated compression garments would affect muscle temperatures was not assessed.
It may have been beneficial to find out how graduated compression garments influence muscle temperature during the varied environmental conditions imposed by field testing.

It is thought that the endurance test was not of sufficient duration to illicit significant fatigue effects on participants in order to highlight detriments or benefits in the skill and sprint test following. It may have been that the chosen participant population was at too higher level of fitness, therefore able to cope with the relatively short duration of tests. Benefits of compression may be more apparent on a less fit population (Higgins, Naughton & Burgess, 2007). There is a test used by Bishop et al (2001) which is proposed to replicate typical movement patterns in field-hockey. The test consists of one minute circuits which are repeated 15 times. In the study by Bishop et al (2001) this test was performed three times with five minutes rest between each test. This test may be more representative for inducing fatigue in field-hockey participants.

# RECOMMENDATIONS FOR FURTHER RESEARCH

The first recommendation would be the need to quantify the benefits of graduated compression garments at enhancing skill performance. It is suggested that this needs to occur in a more controlled environment, using a skill which is less complex and involving minimal components, possibly a test on balance or a darts throwing action.

Related to the above recommendation is the notion that proprioception is something which is learnt and enhanced with practice (Pánics, Tállay, Pavlik & Berkes, 2008; Quinn, 2008; Nottingham, 2006). What would be the effects of graduated compression garments on proprioception training?

Blood lactate concentrations should still be a focus for research with graduated compression garments as there is still a general lack of research in this area regarding actual results rather than inferred results.

Graduated compression garments need to be researched during actual game time or during a simulated match test. This may give a true representation of any possible intermittent endurance benefits which were highlighted in the present study.

Study populations and or levels of participation of participants could be a focus for future research. Do benefits associated with graduated compression garments benefit the elite athlete more than the recreational performer, or vice versa?

# CONCLUSION

The main findings of this study are that graduated compression garments do not improve field hockey skill performance and repeated sprint ability either before of after an intermittent endurance test.

Graduated compression garments do however significantly improve intermittent endurance performance with no associated increase in physiological markers of performance, heart rate, blood lactate and core temperature.

Graduated compression garments did maintain skill and sprint performance at a level comparable to groups performing significantly less in an intermittent endurance test. Therefore graduated compression garments may provide some benefits in terms of reducing fatigue and maintaining performance.

Graduated compression garments were also considered the most comfortable out of the three clothing conditions, and also reduced participants sweating perceptions late on in the test protocol.

It is therefore recommended that graduated compression garments are used in endurance sports which are intermittent in nature such as field hockey, football and rugby.

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# APPENDIX 1

**Letter of ethical approval - removed**

# APPENDIX 2

Jonathan Heath

20th June 2007

Dear Mr Marshall,

My name is Jonathan Heath and I am a Sports Science graduate from the University of Chester. I am currently studying for an MSc in Nutrition and Exercise Science and I am at the stage of writing my thesis. My proposed research is to test the effects of compression garments on field–hockey skill performance and repeated sprint ability following intermittent endurance exercise.

The research gap this study is planning to fill is that, to date there has been no study that tests the effects of compression garments on hockey skill performance. Other areas of interest of this study are the effects on repeated sprint ability and intermittent endurance.

Repeated sprint ability is considered an important and distinguishing characteristic of team sports such as football, rugby and field-hockey. To date there are a small number of pilot studies which have shown trends towards improved repeated sprint ability, but results were not found to be significant.

Intermittent endurance is again an area of study which has received little research regarding compression garments. The majority of research tends to focus on short duration power exercise or continuous exercise to exhaustion. Intermittent endurance is an important aspect of team sports as a participant will be required to perform all aspects of endurance, short bursts of power, periods of steady state running, short periods of recovery, all the time having the pace dictated to them by the opposition.

I would like to know whether this research and its findings would be of interest to Telford & Wrekin Hockey Club and therefore something I could carry out using your first team squad members and facilities. I would be very grateful if you could let me know your response.

Yours sincerely,

Jonathan Heath

**Letter from Telford & WREKIN Hockey Club**

# APPENDIX 3

## POWER ANALYSIS

In order to calculate the required sample size for this study a power analysis was carried out using the G*Power 3.0.4 software (Erdfelder, Faul and Buchner, 1996) down loaded from the internet (http://www.psycho.uni-duesseldorf.de/aap/projects/gpower/).

Previous research using compression garments have identified highly significant differences between groups of participants wearing compression garments and not wearing compression garments. Duffy (2004) found that wearing compression garments during a weight training programme increased ballistic strength by approximately 60% ($p = 0.0001$) compared to a group not wearing compression garments. Lambert (2005a) found graduated compression garments to improve both VO2max and anaerobic threshold ($p = 0.004$ in both cases). Significant results have also been found in blood lactate concentration between wearing and not wearing graduated compression garments ($p < 0.05$) (Lambert and Chow, 2004).

From the results of previous research it was assumed that the effects of this study would be large, therefore the effect size would be $r = 0.5$ (Field, 2005, p.32). The standard $\alpha$-level of 0.05 was adopted (Field, 2005, p.34; Pallant 2005, p.198) and also the recommended power level, $1 - \beta = 0.8$ (80% chance of detecting an effect) (Field, 2005, p.34; Pallant, 2005, p.199). In terms of groups, participants were measured on three separate occasions as part of a repeated measures design.

Using this information the G*Power 3.0.4 software calculated that a total sample size of 14, tested 3 times, would be needed, giving an actual power level of $1 - \beta = 0.803414$.

In light of the above data this study needed 14 participants, tested three times, in order for the study to be considered as having sufficient power.

# APPENDIX 4

**Participant information sheet**

***<u>"DO GRADUATED COMPRESSION GARMENTS IMPROVE FIELD-HOCKEY PERFORMANCE"</u>***

You are being invited to take part in a research study. Before you decide, it is important for you to understand why the research is being done and what it will involve. Please take time to read the following information carefully and discuss it with others if you wish. Ask if there is anything that is not clear or if you would like more information. Take time to decide whether or not you wish to take part.

Thank you for taking the time to read this.

**What is the purpose of the study?**
The aim of this study is to find out if compression garments improve a number of important performance aspects related to field-hockey performance.

**Why have I been chosen?**
You have been chosen because you are an English Hockey League/County 'A' Division standard hockey player.

**Do I have to take part?**
It is up to you to decide whether or not to take part. If you decide to take part you will be given this information sheet to keep and be asked to sign a consent form. If you decide to take part you are still free to withdraw at any time and without giving a reason.

**What will happen to me if I take part?**
You will be required to attend on five separate occasions, two familiarization sessions and three testing sessions. During the sessions you will be required to perform 5 tests in the following order:

1. Hockey Skill Test
2. Repeated Sprint Test
3. Intermittent Endurance Test
4. Hockey Skill Test
5. Repeated Sprint Test

Prior to performing the tests there will be a 15 minute seated rest to gain base line measurements.
Following the tests there will be a 20 minute seated recovery.

You must not have eaten in the two hours previous to turning up and to have refrained from taking part in strenuous exercise 24 hours prior to testing.

During the three testing sessions you will be required to wear a different clothing combination each time. This clothing will be provided for you. As part of the test you will have your height, weight and chest size measured, and heart rate, temperature and blood lactate will be monitored frequently during the test. Each of the five sessions will last approximately 120 minutes. On giving your consent you will be assigned a number so your identity will be confidential and you will not be identifiable in the final report.

**What are the possible disadvantages and risks of taking part?**
You may experience some discomfort whilst taking part in the experiment, but nothing beyond any normal training session or game.

**What are the possible benefits of taking part?**
You may find out that compression garments improve your hockey performance.

**What if something goes wrong?**
If you wish to complain or have any concerns about any aspect of the way you have been approached or treated during the course of this study, please contact Professor Sarah Andrew, Dean of the School of Applied and Health Science, University of Chester, Parkgate Road, Chester, CH1 4BJ, 01244 513055.

If you are harmed by taking part in this research project, there are no special compensation arrangements. If you are harmed due to someone's negligence (but not otherwise), then you may have grounds for legal action but you may have to pay for this.

**Will my taking part in this study be kept confidential?**
All information which is collected about you during the course of the research will be kept strictly confidential so that only the researcher carrying out the research will have access to such information.

**What will happen to the results of the research study?**
The results will be written up as part of a thesis. The results may also be used by the manufacturers of the compression garments for promotional and advertising purposes. Individuals who participate will not be identified in any subsequent report or publication.

**Who is organising and funding the research?**
The research is being organised by Jonathan Heath. There is no funding being provided by any external organisations. Support in providing compression garments for the study is from Skins™.

**Who may I contact for further information?**
If you would like more information about the research before you decide whether or not you would be willing to take part, please contact:

Jonathan Heath: e-mail:

# APPENDIX 5

**Informed Consent form**

***<u>"DO GRADUATED COMPRESSION GARMENTS IMPROVE FIELD-HOCKEY PERFORMANCE"</u>***

Researcher: Mr Jonathan Heath

1. I confirm that I have read and understood the information sheet for the above study and have had the opportunity to ask questions. ☐

2. I understand that my participation is voluntary and that I am free to withdraw at any time, without giving any reason and without my legal rights being affected. ☐

3. I agree to take part in the above study. ☐

| | | |
|---|---|---|
| ______________________ | ________________ | ______________________ |
| Name of participant | Date | Signature |
| ______________________ | ________________ | ______________________ |
| Name of person taking consent (if different from researcher) | Date | Signature |
| ______________________ | ________________ | ______________________ |
| Researcher | Date | Signature |

# APPENDIX 6

**Clothing order of testing**

| Participant # | Control | Placebo | Graduated compression garments |
|---|---|---|---|
| 1 | 1st | 3rd | 2nd |
| 2 | 1st | 3rd | 2nd |
| 3 | 3rd | 1st | 2nd |
| 4 | 3rd | 1st | 2nd |
| 5 | 2nd | 1st | 3rd |
| 6 | 3rd | 2nd | 1st |
| 7 | 2nd | 3rd | 1st |
| 8 | 2nd | 3rd | 1st |
| 9 | 1st | 3rd | 2nd |
| 10 | 2nd | 1st | 3rd |
| 11 | 1st | 2nd | 3rd |
| 12 | 3rd | 2nd | 1st |
| 13 | 1st | 2nd | 3rd |
| 14 | 3rd | 2nd | 1st |

# APPENDIX 7

**CENTRE FOR EXERCISE & NUTRITION SCIENCE**
**Risk Assessment & Contact Details Form**

This form should be completed by CENS students doing work anywhere other than on the premises of the University of Chester

Return form to CENS Research Co-ordinator, Dr Stephen Fallows

Name:…Jonathan Heath…………………………………

Address: White Lodge, Woodlands Road,……………………………

………… Broseley, Shropshire,……………………………………

………… TF12 5PX…………………………………………………………

Brief description of work ………………………………………………………..

Performance testing of Telford & Wrekin Hockey club players

Site of study…St Georges Sports and Social Club……………………….

……………… Church Road, St Georges,……………………………

……………… Telford, TF2 9LU……………………………………………

| |
|---|
| Phone number: 01952 882257………………….. |
| Mobile number: 07730 766126……………. |
| Supervisor…Mike Morris…………………….. |
| Next of kin: Joan Heath……………….... |
| Address and phone number(s) of next of kin…… |
| White Lodge……………………………… |
| Woodlands Road…………………………………… |
| Broseley……………………………………… |
| TF12 5PX…………………………………………… |

Name........Jonathan Heath..............

| Potential Hazard | Control Measures to be Adopted | Agreed as Appropriate by Supervisor (Signature) |
|---|---|---|
| Equipment (goals, weights, nets) | Ensure that all equipment is moved off and to the sides of the astro-turf pitch in order to avoid collision and to provide maximal run off. | |
| Footwear (slipping) | Participants will be required to wear their normal hockey footwear which is designed specifically for use on astro-turf surfaces to provide maximum grip and stability. | |
| | | |
| | | |

**Signatures**

.............................................................

Student

.............................................................

For CENS

# APPENDIX 8

# Pre-Activity Health Status Appraisal

***"DO GRADUATED COMPRESSION GARMENTS IMPROVE FIELD-HOCKEY PERFORMANCE"***

Common sense is your best guide when you answer these questions. Please read the questions carefully and answer each honestly: Tick YES or NO.

**Name of subject**____________________________________
**Date**________________

| Yes | No | |
|---|---|---|
| | | **1.** Has your doctor ever said you have a heart condition and that you should only do physical activity recommended by him/her? |
| | | **2.** Is your doctor currently prescribing drugs (e.g. pain killers) for hay fever, asthma, high or low blood pressure, angina etc.? |
| | | **3.** Are you recovering from any recent medical condition, surgical procedure, or injury? |
| | | **4.** Do you suffer from exercise-induced asthma? |
| | | **5.** Do you have any contagious skin diseases? |
| | | **6.** Do you suffer from epilepsy? |
| | | **7.** Do you suffer from thrombosis or phlebitis? |
| | | **8.** Have you suffered from a cold, flu or respiratory illness recently? |
| | | **9.** Do you know of any other reason why you should not perform this experiment? |

I declare to the best of my knowledge the information given above is correct, and that I know of no reason why I should not take part in this test. I understand that I may withdraw from the study at any time.

**Signature**________________________________ **Date**________________

# APPENDIX 9

**Telford & Wrekin Hockey Club warm up.**

- 5 minutes of moderate intensity continuous running to raise body temperature.

- Dynamic stretching between baseline and 25 yard line:
  - Skipping forward 15 yards and backwards 15 yards.
  - Skipping, high knees and arms forwards and backwards.
  - Hamstring walk, forwards 15 yards and back.
  - Moderate intensity run to 25 yard line and back.
  - High knees forwards and backwards.
  - Heel flicks forwards and backwards.
  - High knees with partial rotation (left knee to right elbow etc)
  - Moderated intensity run to 25 yard line and back.

- Static stretching.
  - Calf stretch using the fence.
  - Groin stretch
  - Quadriceps stretch
  - Lumbar rotation in supine position.
  - Piriformis muscle stretch.

- Dynamic stretching.
  - Moderate intensity run to 25 yard line and back.
  - Lunges.
  - High intensity run to 25 yard line and back
  - Squats.
  - High intensity run to 25 yard line and back.
  - Side steps to 25 yard line, and then higher back to the base line.
  - Walking forwards stretching out the chest. Walking backwards stretching out the back.
  - High intensity run.

- Practice through hockey skill test and sprint test if required.

# APPENDIX 10

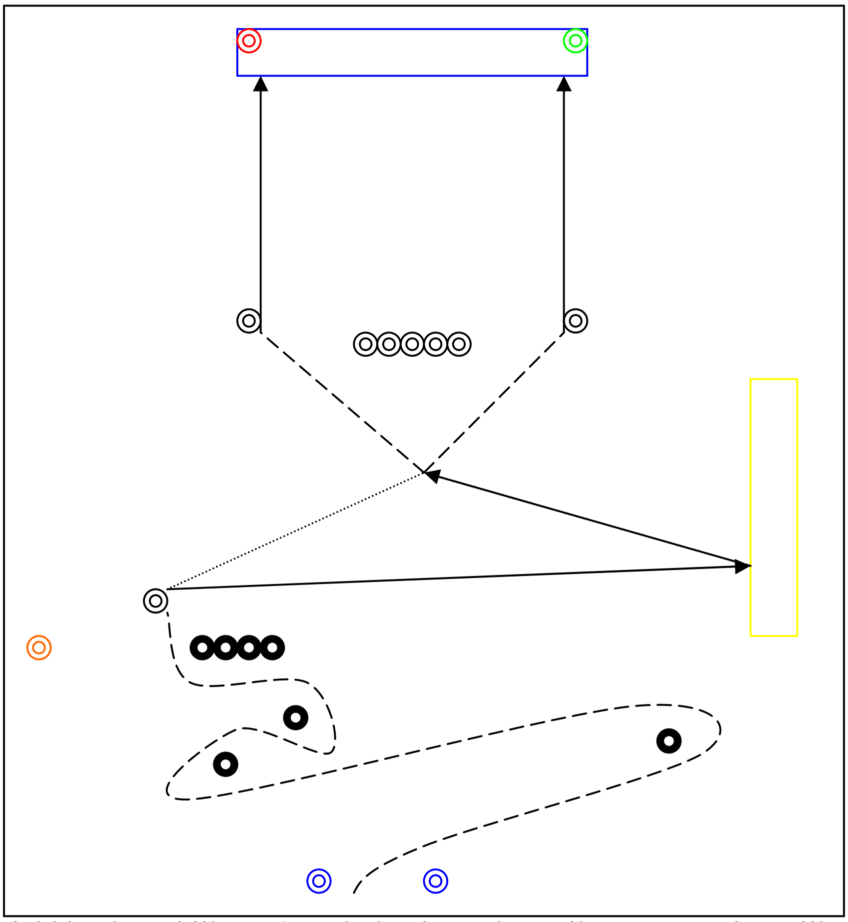


**Figure 1:** Field hockey skill test (Sunderland, Cooke, Milne, Pout and Nevill, 2003).

<u>**Key**</u>

Cone ◎ Start/Finish ◎ cones Dribbling cones

Movement of player with ball – – – – – – – – – – –

Movement of ball only (pass or shot) ⟶

Movements of player only ..........................................

Goal

Rebound board

Cone for verbal command for shooting ◎

Coloured cones for shooting ◎◎

Field hockey skill test (Sunderland, Cooke, Milne, Pout and Nevill, 2003)

- The test is made up of three sections, dribbling, decision time and recovery.
- Participants are required to dribble the ball around the first selection of cones.
- Upon passing the orange cone a verbal instruction referring to the colours in the goal (Red or Green) will be given by the researcher. The order of colours will be randomly set for each clothing condition.
- Participants must then pass and receive the ball using the rebound board.
- Participants will then go on to shoot at the other colour cone to that given by the researcher upon passing the orange cone.
- The test is complete when 6 shots have been taken and the participant then passes the Start/Finish cone.
- Time will be monitored using electronic timing gates (Time-It, Eleiko Sport, Halmstad, Sweden).

1. Timing gates will be situated at the start/finish (blue) cones and the orange cone. This will give a split time for the dribbling section of the test.
2. The researcher will have access to a third timing gate which the researcher will put in a manual input when the ball crosses the goal line. This will give a split time for the decision time section of the test.
3. The time between the manual input by the researcher to when the participant passes through the start/finish gate will be the recovery time

- 2 second time penalties will be given for errors such as touching cones, missing target areas, or incorrect shots.

# APPENDIX 11

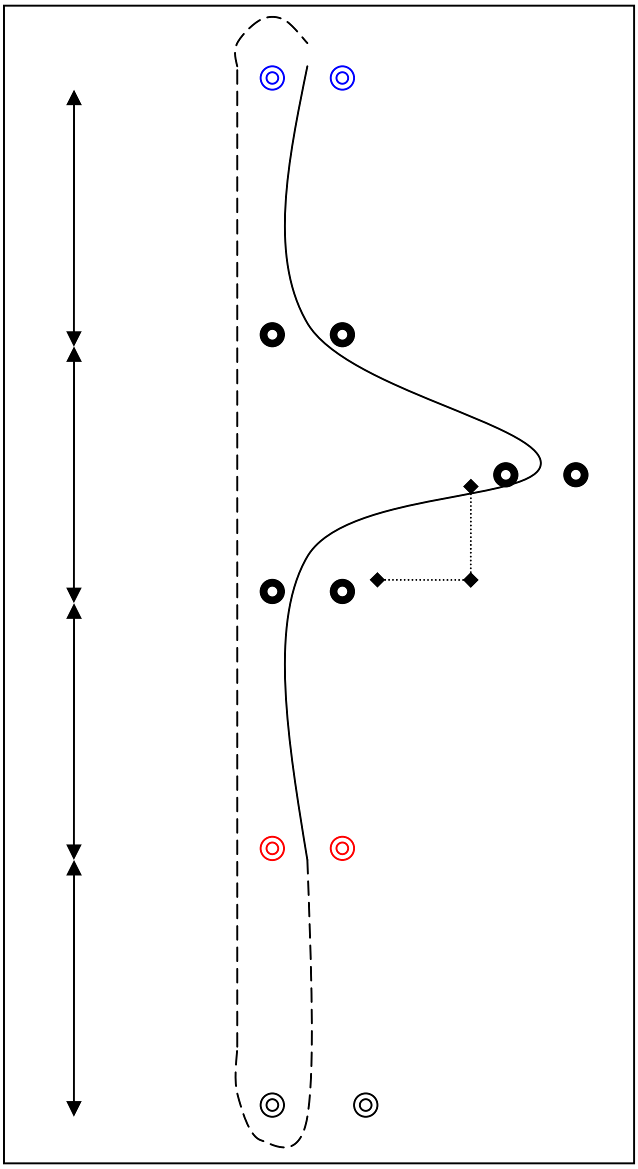


**Figure 2:** Repeated sprint ability test (Bangsbo, 1994, p.82).

**Key**

Cone ◎ Start cones ◎ Finish cones ◎

Sprint

Recovery

10 metres

5 metres

Repeated sprint ability test (Bangsbo, 1994, p.82)

- The test consists of a 30 metre sprint from the blue cones, a change of direction in the middle, and finishing at the red cones.
- This is followed by a low intensity run through the final cones and back up towards the start.
- The recovery period lasts 25 seconds.
- Participants will be counted down with 5 seconds to go to perform the next sprint.
- The test is complete when 7 sprints have been run.
- Time will be monitored using electronic timing gates (Time-It, Eleiko Sport, Halmstad, Sweden) positioned on the blue start cones and the red finish cones.
- Results of the test will show the best time, the mean time and the fatigue time.
- The best time is simply the fastest of the 7 sprints.
- The mean time is the average of the 7 sprints. This expresses a player’s ability to perform several sprints within a short period of time.
- The fatigue time is the difference between the slowest and fastest time. This demonstrates a player’s ability to recover from a sprint.

# APPENDIX 12

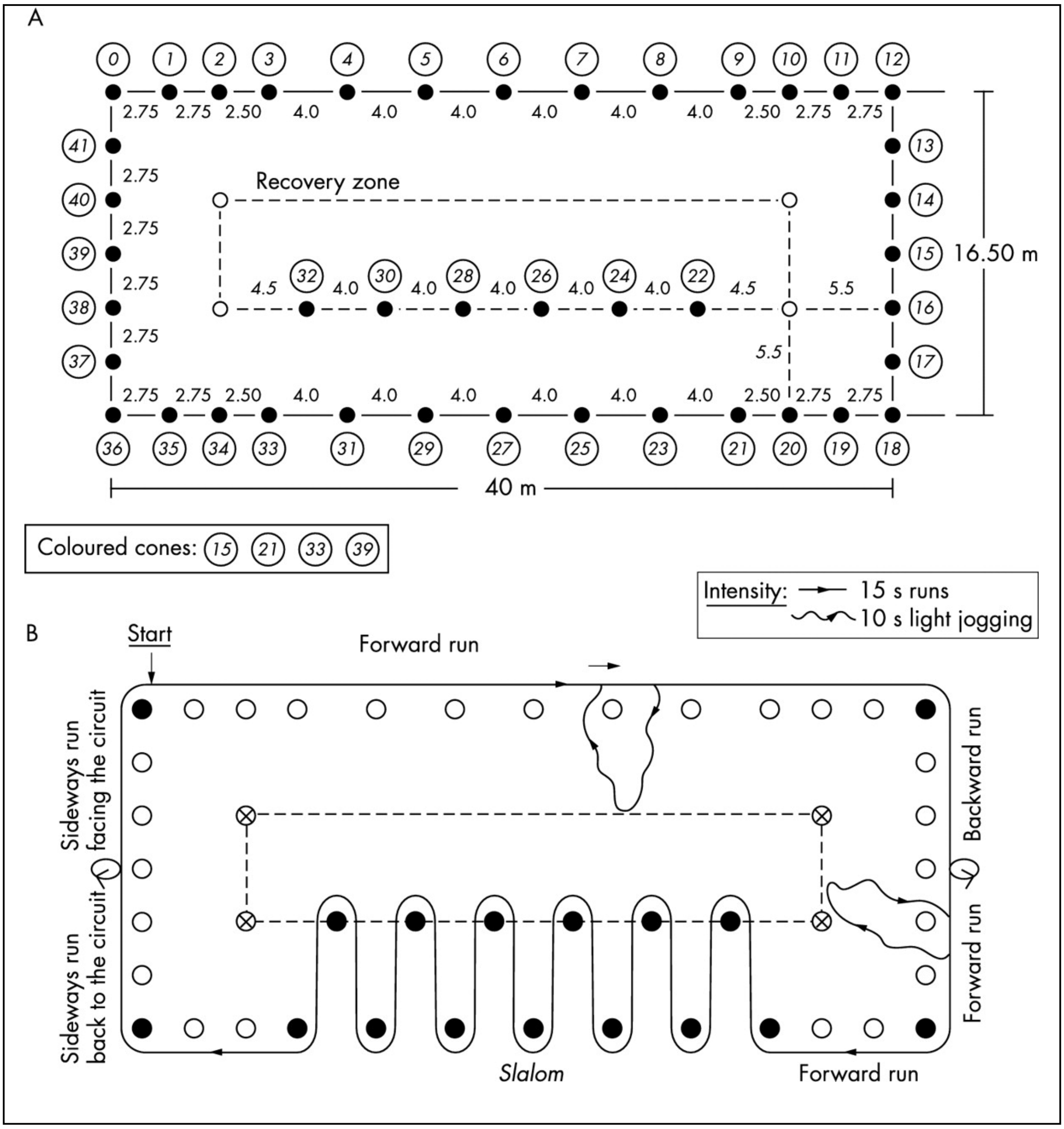



**Figure 3:** Intermittent endurance test (Bangsbo, 1994, p. 88).

Intermittent endurance test (Bangsbo, 1994, p. 88)

- The test consists of a combination of exercises that reflect the intermittent activity pattern of a football game.
- One lap of the test is 160m
- The aim of the test is to complete as many laps as possible in 16.5 minutes.
- The test is split into 15 seconds of high intensity running, followed by 10 seconds of low intensity jogging.
- Running intensity is dictated to participants by a series of audio beeps (or a whistle can be used).
- The symbol 1 in figure 16a indicates backwards running, 2 indicates sideward running facing away from the centre, and 3 indicates sideward running towards the centre.
- During the 10 second recovery period the participant jogs into the central area and then back to the last cone they passed.
- If the participant is in the shaded area during the 10 second recovery period then they jog to the next post and then jog back to the post last passed.
- If participants are between cones when the recovery period is sounded then they should always start the high intensity running from the last cone passed.
- It is important that the markers indicated by ● be posts. This will ensure all subjects are covering the same distance and not cutting corners.

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cone No. | 1 | 2 | 3 | 4 | 5 | 6 | 7 | 8 | 9 |
| Distance (m) | 3 | 6 | 8 | 12 | 16 | 20 | 24 | 28 | 32 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cone No. | 10 | 11 | 12 | 13 | 14 | 15 | 16 | 17 | 18 |
| Distance (m) | 35 | 37 | 40 | 43 | 46 | 48 | 51 | 54 | 57 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cone No. | 19 | 20 | 21 | 22 | 23 | 24 | 25 | 26 | 27 |
| Distance (m) | 59 | 62 | 65 | 70 | 76 | 82 | 88 | 94 | 100 |

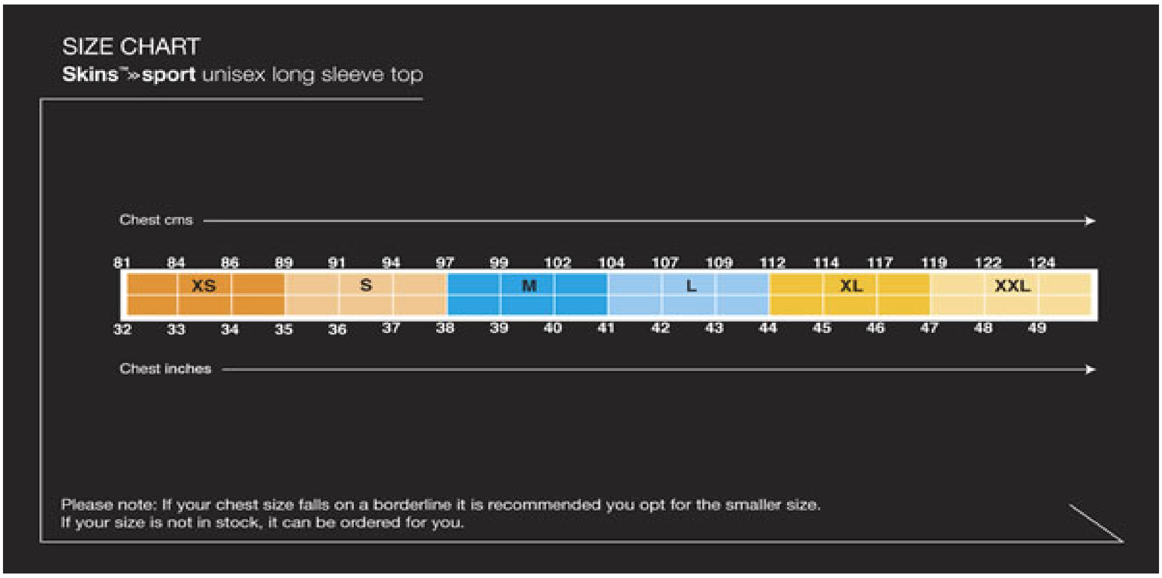
| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cone No. | 28 | 29 | 30 | 31 | 32 | 33 | 34 | 35 | 36 |
| Distance (m) | 105 | 111 | 117 | 123 | 129 | 135 | 137 | 140 | 143 |

| | | | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| Cone No. | 37 | 38 | 39 | 40 | 41 | | | | |
| Distance (m) | 145 | 148 | 151 | 154 | 157 | | | | |

**Table 6:** Cone/Distance conversion table for the intermittent endurance test.

# APPENDIX 13

**Figure 17:** Size chart for graduated compression garment long sleeve top.



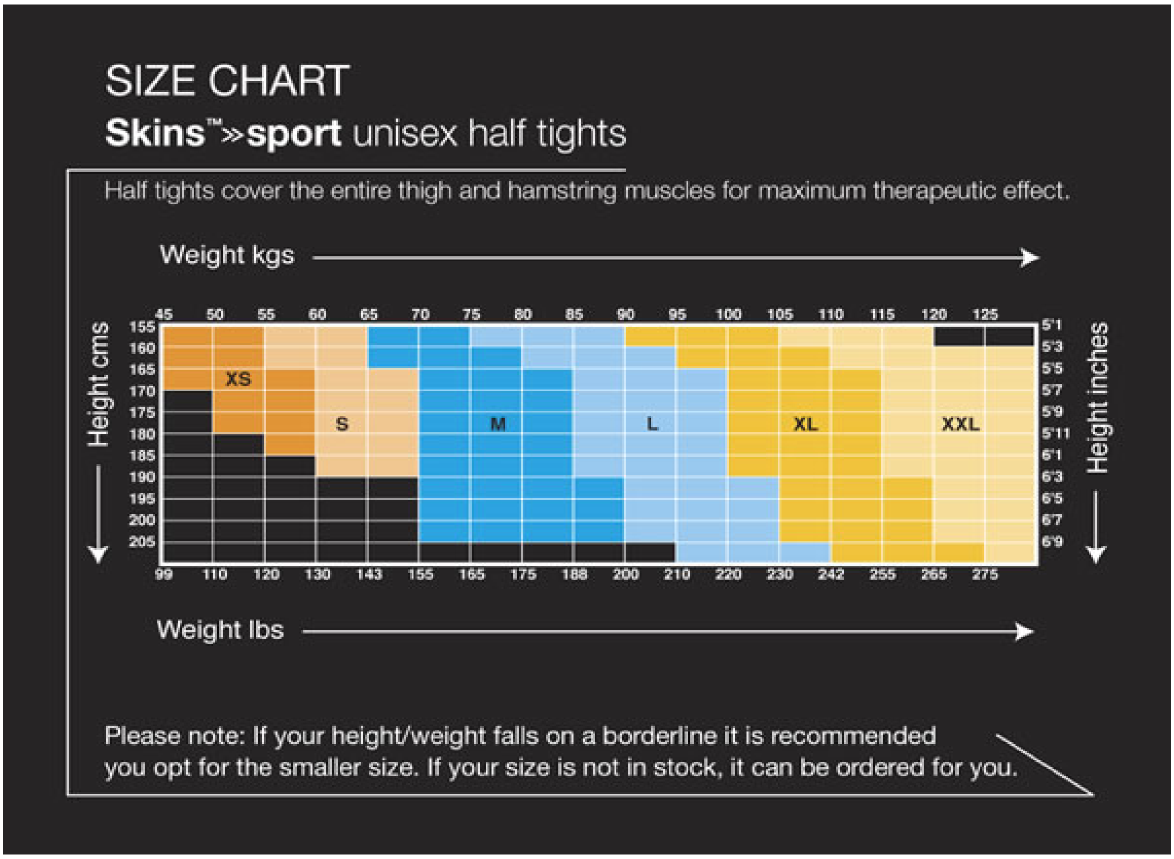




**Figure 18:** Size chart for graduated compression garment shorts.

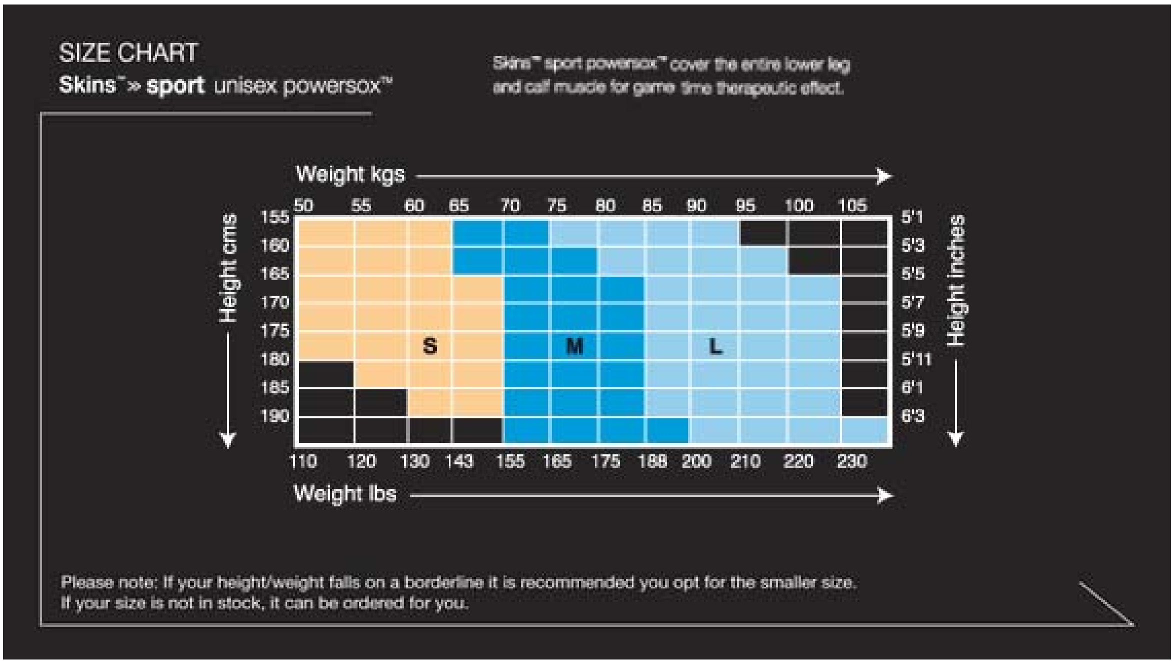



**Figure 19:** Size chart for graduated compression garment socks.

# APPENDIX 14

**How to use the perceived exertion scale** (Borg, 1982)

While doing physical activity, I want you to rate your perception of exertion. This feeling should reflect how heavy and strenuous the exercise feels to you, combining all sensations and feelings of physical stress, effort, and fatigue. Do not concern yourself with any one factor such as leg pain or shortness of breath, but try to focus on your total feeling of exertion.

Look at the rating scale below while you are engaging in an activity; it ranges from 6 to 20, where 6 means "no exertion at all" and 20 means "maximal exertion." Choose the number that best describes your level of exertion. This will give you a good idea of the intensity level of your activity, and you can use this information to speed up or slow down your movements to reach your desired range.

Try to appraise your feeling of exertion as honestly as possible, without thinking about what the actual physical load is. Your own feeling of effort and exertion is important, not how it compares to other people's. Look at the scales and the expressions and then give a number.

RPE Scale (Borg, 1982)

| | |
|---|---|
| 6 | No exertion at all |
| 7 | Extremely light |
| 8 | |
| 9 | Very light |
| 10 | |
| 11 | light |
| 12 | |
| 13 | Somewhat hard |
| 14 | |
| 15 | Hard (Heavy) |
| 16 | |
| 17 | Very hard |
| 18 | |
| 19 | Extremely hard |
| 20 | Maximal exertion |

# APPENDIX 15

Perception of clothing sweating sensation

| | |
|---|---|
| 1 | DRY |
| | |
| 2 | CLAMMY |
| | |
| 3 | MOIST |
| | |
| 4 | WET |
| | |
| 5 | DRIPPING WET |

(Bringard, Perry and Bulluye, 2006; Gavin et al, 2001)

# APPENDIX 16

Clothing comfort sensation

| | |
|---|---|
| 1 | COMFORTABLE |
| | |
| 2 | MODERATELY COMFORTABLE |
| | |
| 3 | A LITTLE COMFORTABLE |
| | |
| 4 | NOT AT ALL |
| | |
| 5 | UNCOMFORTABLE |

(Bringard, Perry and Bulluye, 2006; Ha et al, 1996)

# APPENDIX 17

Whole thermal sensation

| | |
|---|---|
| 1 | VERY HOT |
| | |
| 2 | HOT |
| | |
| 3 | WARM |
| | |
| 4 | SLIGHTLY WARM |
| | |
| 5 | NEUTRAL |
| | |
| 6 | SLIGHTLY COOL |
| | |
| 7 | COOL |
| | |
| 8 | COLD |
| | |
| 9 | VERY COLD |

(Bringard, Perry and Bulluye, 2006; Ha et al, 1996)

# APPENDIX 18

## ENVIRONMENTAL TEMPERATURE

### EXERCISE PROTOCOL

**Table 7: Normality test for environmental temperature during the exercise protocol. Mean temperature for placebo was not normally distributed.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| TestTempControl | .157 | 14 | .200(*) | .928 | 14 | .283 |
| TestTempPlacebo | .213 | 14 | .085 | .865 | 14 | .036 |
| TestTempGCG | .122 | 14 | .200(*) | .985 | 14 | .993 |

* This is a lower bound of the true significance.
A Lilliefors Significance Correction

**Table 8: Friedmans ANOVA for environmental temperature during the exercise protocol.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 4.429 |
| Df | 2 |
| Asymp. Sig. | .109 |

## RECOVERY PROTOCOL

**Table 9: Normality test for environmental temperature during the recovery protocol.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| RecoveryTempControl | .188 | 14 | .194 | .894 | 14 | .093 |
| RecoveryTempPlacebo | .090 | 14 | .200(*) | .980 | 14 | .973 |
| RecoveryTempGCG | .159 | 14 | .200(*) | .948 | 14 | .528 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 10: Mauchly's test of Sphericity for recovery environmental temperature.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .984 | .194 | 2 | .908 | .984 | 1.000 | .500 |

**Table 11: Tests of within subjects effects for recovery environmental temperature.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | 3.510 | 2 | 1.755 | 1.167 | .327 |
| | Greenhouse-Geisser | 3.510 | 1.968 | 1.783 | 1.167 | .327 |
| | Huynh-Feldt | 3.510 | 2.000 | 1.755 | 1.167 | .327 |
| | Lower-bound | 3.510 | 1.000 | 3.510 | 1.167 | .300 |
| Error(cond) | Sphericity Assumed | 39.090 | 26 | 1.503 | | |
| | Greenhouse-Geisser | 39.090 | 25.590 | 1.528 | | |
| | Huynh-Feldt | 39.090 | 26.000 | 1.503 | | |
| | Lower-bound | 39.090 | 13.000 | 3.007 | | |

## ENVIRONMENTAL HUMIDITY

### EXERCISE PROTOCOL

**Table 12: Normality test for environmental humidity for the exercise protocol. Mean results for placebo were not normally distributed.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| TestHumidityControl | .178 | 14 | .200(*) | .877 | 14 | .053 |
| TestHumidityPlacebo | .210 | 14 | .095 | .872 | 14 | .045 |
| TestHumidityGCG | .187 | 14 | .198 | .910 | 14 | .158 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 13: Friedmans ANOVA for environmental humidity for the exercise protocol.**

| | |
|---|---|
| N | 14 |
| Chi-Square | .444 |
| Df | 2 |
| Asymp. Sig. | .801 |

## RECOVERY PROTOCOL

**Table 14: Normality test for environmental humidity for the recovery protocol.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| RecoveryHumidityControl | .223 | 14 | .056 | .905 | 14 | .135 |
| RecoveryHumidityPlacebo | .211 | 14 | .092 | .951 | 14 | .573 |
| RecoveryHumidityGCG | .180 | 14 | .200(*) | .956 | 14 | .665 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 15: Mauchly's test of Sphericity for environmental humidity for the recovery protocol.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | Df | Sig. | Epsilon(a) Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
|---|---|---|---|---|---|---|---|
| Cond | .725 | 3.858 | 2 | .145 | .784 | .873 | .500 |

**Table 16: Tests of within subjects effects for environmental humidity for the recovery protocol.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | 20.619 | 2 | 10.310 | .356 | .704 |
| | Greenhouse-Geisser | 20.619 | 1.569 | 13.144 | .356 | .653 |
| | Huynh-Feldt | 20.619 | 1.746 | 11.807 | .356 | .676 |
| | Lower-bound | 20.619 | 1.000 | 20.619 | .356 | .561 |
| Error(cond) | Sphericity Assumed | 752.048 | 26 | 28.925 | | |
| | Greenhouse-Geisser | 752.048 | 20.394 | 36.877 | | |
| | Huynh-Feldt | 752.048 | 22.702 | 33.127 | | |
| | Lower-bound | 752.048 | 13.000 | 57.850 | | |

# HOCKEY SKILL TEST

## TOTAL TIME

**Table 17: Normality tests for hockey skill test total times, pre and post intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SkillControlPreTotalTime | .244 | 14 | .023 | .897 | 14 | .101 |
| SkillPlaceboPreTotalTime | .136 | 14 | .200(*) | .966 | 14 | .818 |
| SkillGCGPreTotalTime | .132 | 14 | .200(*) | .950 | 14 | .559 |
| SkillControlPostTotalTime | .149 | 14 | .200(*) | .971 | 14 | .891 |
| SkillPlaceboPostTotalTime | .148 | 14 | .200(*) | .954 | 14 | .618 |
| SkillGCGPostTotalTime | .106 | 14 | .200(*) | .977 | 14 | .955 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 18: Mauchly's test of Sphericity for hockey skill test total time pre intermittent endurance.**

| | | | | | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | Df | Sig. | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .903 | 1.221 | 2 | .543 | .912 | 1.000 | .500 |

**Table 19: Tests of within subjects effects for hockey skill test total time pre intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | 10.509 | 2 | 5.254 | .225 | .800 |
| | Greenhouse-Geisser | 10.509 | 1.824 | 5.763 | .225 | .780 |
| | Huynh-Feldt | 10.509 | 2.000 | 5.254 | .225 | .800 |
| | Lower-bound | 10.509 | 1.000 | 10.509 | .225 | .643 |
| Error(cond) | Sphericity Assumed | 606.018 | 26 | 23.308 | | |
| | Greenhouse-Geisser | 606.018 | 23.707 | 25.563 | | |
| | Huynh-Feldt | 606.018 | 26.000 | 23.308 | | |
| | Lower-bound | 606.018 | 13.000 | 46.617 | | |

**Table 20: Mauchly's test of Sphericity for hockey skill test total time post intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .970 | .361 | 2 | .835 | .971 | 1.000 | .500 |

**Table 21: Tests of within subjects effects for hockey skill test total time post intermittent endurance.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | 11.712 | 2 | 5.856 | .198 | .822 |
| | Greenhouse-Geisser | 11.712 | 1.942 | 6.030 | .198 | .816 |
| | Huynh-Feldt | 11.712 | 2.000 | 5.856 | .198 | .822 |
| | Lower-bound | 11.712 | 1.000 | 11.712 | .198 | .664 |
| Error(cond) | Sphericity Assumed | 769.751 | 26 | 29.606 | | |
| | Greenhouse-Geisser | 769.751 | 25.252 | 30.483 | | |
| | Huynh-Feldt | 769.751 | 26.000 | 29.606 | | |
| | Lower-bound | 769.751 | 13.000 | 59.212 | | |

## TOTAL TIME T-TESTS

**Table 22: Paired samples t-test comparing hockey skill test total time pre and post intermittent endurance test within clothing conditions.**

| | | Paired Differences | | | | | t | df | Sig. (2-tailed) |
|---|---|---|---|---|---|---|---|---|---|
| | | Mean | Std. Deviation | Std. Error Mean | 95% Confidence Interval of the Difference Lower | Upper | | | |
| Pair 1 | SkillControlTotalTimePre - SkillControlTotalTimePost | .15786 | .98052 | .26205 | -.40828 | .72399 | .602 | 13 | .557 |
| Pair 2 | SkillPlaceboTotalTimePre - SkillPlaceboTotalTimePost | .12857 | 1.36965 | .36605 | -.66224 | .91938 | .351 | 13 | .731 |
| Pair 3 | SkillGCGTotalTimePre - SkillGCGTotalTimePost | .08929 | 1.22600 | .32766 | -.61858 | .79716 | .272 | 13 | .790 |

## SKILL TEST COMPONENTS PRE INTERMITTENT ENDURANCE TEST

**Table 23: Normality tests for all the hockey skill test components pre intermittent endurance test. Decision making data and penalty data were not normally distributed.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SkillControlDribblePre | .143 | 14 | .200(*) | .963 | 14 | .780 |
| SkillPlaceboDribblePre | .155 | 14 | .200(*) | .956 | 14 | .663 |
| SkillGCGDribblePre | .132 | 14 | .200(*) | .954 | 14 | .616 |
| SkillContDecissionPre | .195 | 14 | .156 | .904 | 14 | .128 |
| SkillPlacDecissionPre | .105 | 14 | .200(*) | .965 | 14 | .805 |
| SkillGCGDecissionPre | .188 | 14 | .192 | .866 | 14 | .036 |
| SkillControlRecoveryPre | .211 | 14 | .093 | .879 | 14 | .057 |
| SkillPlaceboRecoveryPre | .185 | 14 | .200(*) | .950 | 14 | .557 |
| SkillGCGRecoveryPre | .183 | 14 | .200(*) | .882 | 14 | .063 |
| SkillControlPenaltyPre | .245 | 14 | .022 | .841 | 14 | .017 |
| SkillPlaceboPenaltyPre | .271 | 14 | .006 | .861 | 14 | .031 |
| SkillGCGPenaltyPre | .179 | 14 | .200(*) | .913 | 14 | .176 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

## DRIBBLE COMPONENT

**Table 24: Mauchly's test of Sphericity for hockey skill test dribble component pre intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .798 | 2.701 | 2 | .259 | .832 | .940 | .500 |

**Table 25: Tests of within subjects effects for hockey skill test dribble component pre intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .026 | 2 | .013 | .198 | .822 |
| | Greenhouse-Geisser | .026 | 1.665 | .016 | .198 | .783 |
| | Huynh-Feldt | .026 | 1.879 | .014 | .198 | .809 |
| | Lower-bound | .026 | 1.000 | .026 | .198 | .664 |
| Error(cond) | Sphericity Assumed | 1.731 | 26 | .067 | | |
| | Greenhouse-Geisser | 1.731 | 21.639 | .080 | | |
| | Huynh-Feldt | 1.731 | 24.432 | .071 | | |
| | Lower-bound | 1.731 | 13.000 | .133 | | |

## DECISION MAKING COMPONENT

**Table 26: Friedmans ANOVA for hockey skill test decision making component pre intermittent endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 1.714 |
| Df | 2 |
| Asymp. Sig. | .424 |

## RECOVERY COMPONENT

**Table 27: Mauchly's test of Sphericity for hockey skill test recovery component pre intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .853 | 1.909 | 2 | .385 | .872 | .995 | .500 |

**Table 28: Tests of within subjects effects for hockey skill test recovery component pre intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .079 | 2 | .039 | .270 | .766 |
| | Greenhouse-Geisser | .079 | 1.744 | .045 | .270 | .736 |
| | Huynh-Feldt | .079 | 1.991 | .039 | .270 | .765 |
| | Lower-bound | .079 | 1.000 | .079 | .270 | .612 |
| Error(cond) | Sphericity Assumed | 3.792 | 26 | .146 | | |
| | Greenhouse-Geisser | 3.792 | 22.666 | .167 | | |
| | Huynh-Feldt | 3.792 | 25.881 | .147 | | |
| | Lower-bound | 3.792 | 13.000 | .292 | | |

## PENALTIES COMPONENT

**Table 29: Friedmans ANOVA for hockey skill test penalties component pre intermittent endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | .727 |
| Df | 2 |
| Asymp. Sig. | .695 |

a Friedman Test

## SKILL TEST COMPONENTS POST INTERMITTENT ENDURANCE TEST

**Table 30: Normality tests for hockey skill test components post intermittent endurance test. Penalty component data was not normally distributed.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SkillControlDribblePost | .117 | 14 | .200(*) | .954 | 14 | .616 |
| SkillPlaceboDribblePost | .132 | 14 | .200(*) | .947 | 14 | .510 |
| SkillGCGDribblePost | .151 | 14 | .200(*) | .949 | 14 | .540 |
| SkillContDecissionPost | .167 | 14 | .200(*) | .959 | 14 | .705 |
| SkillPlacDecissionPost | .150 | 14 | .200(*) | .901 | 14 | .115 |
| SkillGCGDecissionPost | .165 | 14 | .200(*) | .948 | 14 | .525 |
| SkillControlRecoveryPost | .215 | 14 | .079 | .893 | 14 | .089 |
| SkillPlaceboRecoveryPost | .162 | 14 | .200(*) | .897 | 14 | .102 |
| SkillGCGRecoveryPost | .130 | 14 | .200(*) | .981 | 14 | .978 |
| SkillControlPenaltyPost | .196 | 14 | .152 | .874 | 14 | .048 |
| SkillPlaceboPenaltyPost | .201 | 14 | .130 | .876 | 14 | .051 |
| SkillGCGPenaltyPost | .205 | 14 | .115 | .928 | 14 | .283 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**DRIBBLE COMPONENT**

**Table 31: Mauchly's test of Sphericity for hockey skill test dribble component post intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .982 | .222 | 2 | .895 | .982 | 1.000 | .500 |

**Table 32: Tests of within subjects effects for hockey skill test dribble component post intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .033 | 2 | .016 | .172 | .843 |
| | Greenhouse-Geisser | .033 | 1.964 | .017 | .172 | .839 |
| | Huynh-Feldt | .033 | 2.000 | .016 | .172 | .843 |
| | Lower-bound | .033 | 1.000 | .033 | .172 | .685 |
| Error(cond) | Sphericity Assumed | 2.482 | 26 | .095 | | |
| | Greenhouse-Geisser | 2.482 | 25.532 | .097 | | |
| | Huynh-Feldt | 2.482 | 26.000 | .095 | | |
| | Lower-bound | 2.482 | 13.000 | .191 | | |

## DECISION COMPONENT

**Table 33: Mauchly's test of Sphericity for hockey skill test decision component post intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .860 | 1.807 | 2 | .405 | .877 | 1.000 | .500 |

**Table 34: Tests of within subjects for hockey skill test decision component post intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .137 | 2 | .069 | .838 | .444 |
| | Greenhouse-Geisser | .137 | 1.755 | .078 | .838 | .432 |
| | Huynh-Feldt | .137 | 2.000 | .069 | .838 | .444 |
| | Lower-bound | .137 | 1.000 | .137 | .838 | .377 |
| Error(cond) | Sphericity Assumed | 2.129 | 26 | .082 | | |
| | Greenhouse-Geisser | 2.129 | 22.810 | .093 | | |
| | Huynh-Feldt | 2.129 | 26.000 | .082 | | |
| | Lower-bound | 2.129 | 13.000 | .164 | | |

## RECOVERY COMPONENT

**Table 35: Mauchleys test of Sphericity for hockey skill test recovery component post intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .875 | 1.608 | 2 | .448 | .889 | 1.000 | .500 |

**Table 36: Tests of within subjects effects for hockey skill test recovery component post intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .081 | 2 | .041 | .360 | .701 |
| | Greenhouse-Geisser | .081 | 1.777 | .046 | .360 | .677 |
| | Huynh-Feldt | .081 | 2.000 | .041 | .360 | .701 |
| | Lower-bound | .081 | 1.000 | .081 | .360 | .559 |
| Error(cond) | Sphericity Assumed | 2.938 | 26 | .113 | | |
| | Greenhouse-Geisser | 2.938 | 23.103 | .127 | | |
| | Huynh-Feldt | 2.938 | 26.000 | .113 | | |
| | Lower-bound | 2.938 | 13.000 | .226 | | |

## PENALTIES COMPONENT

**Table 37: Friedmans ANOVA for hockey skill test penalties component post intermittent endurance test**

| | |
|---|---|
| N | 14 |
| Chi-Square | .760 |
| Df | 2 |
| Asymp. Sig. | .684 |

# REPEATED SPRINT ABILITY

## FATIGUE TIME PRE

**Table 38: Tests of normality for repeated sprint ability fatigue time pre intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPre Fatiguetime | .262 | 14 | .010 | .808 | 14 | .006 |
| SprintPlaceboPre Fatiguetime | .095 | 14 | .200(*) | .989 | 14 | .999 |
| SprintGCGPreFat iguetime | .193 | 14 | .166 | .857 | 14 | .028 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 39: Friedmans ANOVA for repeated sprint ability fatigue time pre intermittent endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 1.000 |
| Df | 2 |
| Asymp. Sig. | .607 |

## FATIGUE TIME POST

**Table 40: Normality test for repeated sprint ability fatigue time post intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPost Fatiguetime | .364 | 14 | .000 | .567 | 14 | .000 |
| SprintPlaceboPost Fatiguetime | .235 | 14 | .035 | .844 | 14 | .018 |
| SprintGCGPostFa tiguetime | .228 | 14 | .047 | .761 | 14 | .002 |

a Lilliefors Significance Correction

**Table 41: Friedmans ANOVA statistic for repeated sprint ability fatigue time post intermittent endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 8.982 |
| Df | 2 |
| Asymp. Sig. | .011 |

a Friedman Test

**Table 42: Wilcoxon matched pairs output for repeated sprint ability fatigue time post intermittent endurance test.**

| | SprintPlaceboPostFatiguetime - SprintControlPostFatiguetime | SprintGCGPostFatiguetime - SprintControlPostFatiguetime | SprintGCGPostFatiguetime - SprintPlaceboPostFatiguetime |
|---|---|---|---|
| Z | -2.828(a) | -1.790(a) | -.314(b) |
| Asymp. Sig. (2-tailed) | .005 | .073 | .753 |

a Based on positive ranks.
b Based on negative ranks.
c Wilcoxon Signed Ranks Test

## FASTEST SPRINT PRE

**Table 43: Normality tests for repeated sprint ability fastest sprint pre intermittent endurance run.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPreFastest | .148 | 14 | .200(*) | .959 | 14 | .707 |
| SprintPlaceboPreFastest | .156 | 14 | .200(*) | .977 | 14 | .950 |
| SprintGCGPreFastest | .171 | 14 | .200(*) | .934 | 14 | .351 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 44: Mauchly's test of sphericity for repeated sprint ability fastest sprint pre intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .576 | 6.624 | 2 | .036 | .702 | .762 | .500 |

**Table 45: Tests of within subjects effects for repeated sprint ability fastest sprint pre intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .052 | 2 | .026 | .485 | .621 |
| | **Greenhouse-Geisser** | **.052** | **1.404** | **.037** | **.485** | **.558** |
| | Huynh-Feldt | .052 | 1.523 | .034 | .485 | .572 |
| | Lower-bound | .052 | 1.000 | .052 | .485 | .498 |
| Error(cond) | Sphericity Assumed | 1.380 | 26 | .053 | | |
| | Greenhouse-Geisser | 1.380 | 18.256 | .076 | | |
| | Huynh-Feldt | 1.380 | 19.799 | .070 | | |
| | Lower-bound | 1.380 | 13.000 | .106 | | |

## FASTEST SPRINT POST

**Table 46: Normality tests for repeated sprint ability fastes sprint post intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPostFastest | .206 | 14 | .111 | .851 | 14 | .023 |
| SprintPlaceboPostFastest | .153 | 14 | .200(*) | .932 | 14 | .325 |
| SprintGCGPostFastest | .160 | 14 | .200(*) | .923 | 14 | .239 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 47: Friedmans ANOVA for repeated sprint ability fastest time post intermittent endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 1.815 |
| Df | 2 |
| Asymp. Sig. | .404 |

## SLOWEST SPRINT PRE

**Table 48: Normality tests for repeated sprint ability slowest sprint pre intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPreSlowest | .146 | 14 | .200(*) | .932 | 14 | .322 |
| SprintPlaceboPreSlowest | .231 | 14 | .040 | .929 | 14 | .297 |
| SprintGCGPreSlowest | .179 | 14 | .200(*) | .918 | 14 | .207 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 49: Mauchly's test of sphericity for repeated sprint ability test slowest sprint pre intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .501 | 8.303 | 2 | .016 | .667 | .715 | .500 |

**Table 50: Tests of within subjects effects for repeated sprint ability test slowest sprint pre intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .077 | 2 | .039 | .359 | .702 |
| | **Greenhouse-Geisser** | **.077** | **1.334** | **.058** | **.359** | **.618** |
| | Huynh-Feldt | .077 | 1.429 | .054 | .359 | .633 |
| | Lower-bound | .077 | 1.000 | .077 | .359 | .559 |
| Error(cond) | Sphericity Assumed | 2.794 | 26 | .107 | | |
| | Greenhouse-Geisser | 2.794 | 17.340 | .161 | | |
| | Huynh-Feldt | 2.794 | 18.581 | .150 | | |
| | Lower-bound | 2.794 | 13.000 | .215 | | |

## SLOWEST SPRINT POST

**Table 51: Normality tests for repeated sprint ability test slowest sprint post intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPostSlowest | .145 | 14 | .200(*) | .924 | 14 | .254 |
| SprintPlaceboPostSlowest | .150 | 14 | .200(*) | .923 | 14 | .244 |
| SprintGCGPostSloest | .265 | 14 | .009 | .866 | 14 | .037 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 52: Friedmans ANOVA for repeated sprint ability test slowest sprint post intermittent endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 2.286 |
| Df | 2 |
| Asymp. Sig. | .319 |

## MEAN SPRINT TIME PRE

**Table 53: Tests of normality for repeated sprint ability test mean sprint time pre intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPreMean | .181 | 14 | .200(*) | .950 | 14 | .563 |
| SprintPlaceboPreMean | .186 | 14 | .200(*) | .945 | 14 | .481 |
| SprintGCGPreMean | .149 | 14 | .200(*) | .953 | 14 | .610 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 54: Mauchly's test of sphericity for repeated sprint ability test mean sprint times pre intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .569 | 6.763 | 2 | .034 | .699 | .757 | .500 |

**Table 55: Tests of within subjects effects for repeated sprint ability test mean sprint time pre intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .016 | 2 | .008 | .173 | .842 |
| | **Greenhouse-Geisser** | **.016** | **1.398** | **.011** | **.173** | **.764** |
| | Huynh-Feldt | .016 | 1.514 | .010 | .173 | .783 |
| | Lower-bound | .016 | 1.000 | .016 | .173 | .684 |
| Error(cond) | Sphericity Assumed | 1.187 | 26 | .046 | | |
| | Greenhouse-Geisser | 1.187 | 18.171 | .065 | | |
| | Huynh-Feldt | 1.187 | 19.685 | .060 | | |
| | Lower-bound | 1.187 | 13.000 | .091 | | |

## MEAN SPRINT TIME POST

**Table 56: Normality tests for repeated sprint ability test mean sprint times post intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| SprintControlPostMean | .121 | 14 | .200(*) | .919 | 14 | .211 |
| SprintPlaceboPostMean | .143 | 14 | .200(*) | .932 | 14 | .326 |
| SprintGCGPostMean | .155 | 14 | .200(*) | .930 | 14 | .305 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 57: Mauchly's test of sphericity for repeated sprint ability test mean sprint time post intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .672 | 4.766 | 2 | .092 | .753 | .830 | .500 |

**Table 58: Tests of within subjects effects for repeated sprint ability test mean sprint time post intermittent endurance test.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .025 | 2 | .013 | .153 | .859 |
| | Greenhouse-Geisser | .025 | 1.506 | .017 | .153 | .799 |
| | Huynh-Feldt | .025 | 1.661 | .015 | .153 | .821 |
| | Lower-bound | .025 | 1.000 | .025 | .153 | .702 |
| Error(cond) | Sphericity Assumed | 2.161 | 26 | .083 | | |
| | Greenhouse-Geisser | 2.161 | 19.582 | .110 | | |
| | Huynh-Feldt | 2.161 | 21.590 | .100 | | |
| | Lower-bound | 2.161 | 13.000 | .166 | | |

## INTERMITTENT ENDURANCE

**Table 59: Normality test for intermittent endurance test.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| controlendur | .195 | 14 | .158 | .953 | 14 | .612 |
| placeboendur | .179 | 14 | .200(*) | .956 | 14 | .649 |
| GCGendur | .192 | 14 | .170 | .964 | 14 | .796 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 60: Mauchly's test of Shpericity for intermittent endurance test.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Condition | .916 | 1.054 | 2 | .590 | .922 | 1.000 | .500 |

**Table 61: Tests of within-subjects effects for intermittent endurance**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Condition | Sphericity Assumed | 57159.571 | 2 | 28579.786 | 13.086 | .000 |
| | Greenhouse-Geisser | 57159.571 | 1.845 | 30983.446 | 13.086 | .000 |
| | Huynh-Feldt | 57159.571 | 2.000 | 28579.786 | 13.086 | .000 |
| | Lower-bound | 57159.571 | 1.000 | 57159.571 | 13.086 | .003 |
| Error(condition) | Sphericity Assumed | 56782.429 | 26 | 2183.940 | | |
| | Greenhouse-Geisser | 56782.429 | 23.983 | 2367.617 | | |
| | Huynh-Feldt | 56782.429 | 26.000 | 2183.940 | | |
| | Lower-bound | 56782.429 | 13.000 | 4367.879 | | |

**Table 62: Pairwise comparisons between clothing trials for intermittent endurance. (1 = Control, 2 = Placebo, 3 = GCG)**

| (I) condition | (J) condition | Mean Difference (I-J) | Std. Error | Sig.(a) | 95% Confidence Interval for Difference(a) | |
|---|---|---|---|---|---|---|
| | | | | | Lower Bound | Upper Bound |
| 1 | 2 | 17.857 | 18.221 | 1.000 | -32.175 | 67.890 |
| | 3 | -67.786(*) | 15.019 | .002 | -109.027 | -26.544 |
| 2 | 1 | -17.857 | 18.221 | 1.000 | -67.890 | 32.175 |
| | 3 | -85.643(*) | 19.453 | .002 | -139.059 | -32.227 |
| 3 | 1 | 67.786(*) | 15.019 | .002 | 26.544 | 109.027 |
| | 2 | 85.643(*) | 19.453 | .002 | 32.227 | 139.059 |

Based on estimated marginal means
* The mean difference is significant at the .05 level.
a Adjustment for multiple comparisons: Bonferroni.

# PHYSIOLOGICAL DATA

## HEART RATE

**Table 63: Normality tests for mean heart rates.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| HeartRateMeanControl | .227 | 14 | .048 | .914 | 14 | .178 |
| HeartRateMeanPlacebo | .125 | 14 | .200(*) | .955 | 14 | .639 |
| HeartRateMeanGCG | .145 | 14 | .200(*) | .959 | 14 | .709 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 64: Mauchly's test of sphericity for mean heart rates.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .998 | .028 | 2 | .986 | .998 | 1.000 | .500 |

**Table 65: Tests of within subjects effects for mean heart rates.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | 29.476 | 2 | 14.738 | .691 | .510 |
| | Greenhouse-Geisser | 29.476 | 1.995 | 14.772 | .691 | .510 |
| | Huynh-Feldt | 29.476 | 2.000 | 14.738 | .691 | .510 |
| | Lower-bound | 29.476 | 1.000 | 29.476 | .691 | .421 |
| Error(cond) | Sphericity Assumed | 554.524 | 26 | 21.328 | | |
| | Greenhouse-Geisser | 554.524 | 25.940 | 21.377 | | |
| | Huynh-Feldt | 554.524 | 26.000 | 21.328 | | |
| | Lower-bound | 554.524 | 13.000 | 42.656 | | |

## BLOOD LACTATE

**Table 66: Normality tests for mean blood lactate.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| BloodLactateMeanControl | .149 | 14 | .200(*) | .926 | 14 | .267 |
| BloodLactateMeanPlacebo | .225 | 14 | .052 | .879 | 14 | .057 |
| BloodLactateMeanGCG | .199 | 14 | .136 | .900 | 14 | .114 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 67: Mauchly's test of sphericity for mean blood lactate.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .933 | .831 | 2 | .660 | .937 | 1.000 | .500 |

**Table 68: Tests of within subjects effects for mean blood lactate.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .299 | 2 | .150 | .113 | .893 |
| | Greenhouse-Geisser | .299 | 1.875 | .160 | .113 | .881 |
| | Huynh-Feldt | .299 | 2.000 | .150 | .113 | .893 |
| | Lower-bound | .299 | 1.000 | .299 | .113 | .742 |
| Error(cond) | Sphericity Assumed | 34.274 | 26 | 1.318 | | |
| | Greenhouse-Geisser | 34.274 | 24.369 | 1.406 | | |
| | Huynh-Feldt | 34.274 | 26.000 | 1.318 | | |
| | Lower-bound | 34.274 | 13.000 | 2.636 | | |

## CORE TEMPERATURE

**Table 69: Normality test for mean core temperatures.**

| | Kolmogorov-Smirnov(a) | | | Shapiro-Wilk | | |
|---|---|---|---|---|---|---|
| | Statistic | df | Sig. | Statistic | df | Sig. |
| controlcoretemp | .128 | 14 | .200(*) | .938 | 14 | .393 |
| placebocoretemp | .111 | 14 | .200(*) | .983 | 14 | .987 |
| GCGcoretemp | .118 | 14 | .200(*) | .960 | 14 | .730 |

* This is a lower bound of the true significance.
a Lilliefors Significance Correction

**Table 70: Mauchly's test of sphericity for mean core temperature.**

| Within Subjects Effect | Mauchly's W | Approx. Chi-Square | df | Sig. | Epsilon(a) | | |
|---|---|---|---|---|---|---|---|
| | | | | | Greenhouse-Geisser | Huynh-Feldt | Lower-bound |
| Cond | .890 | 1.394 | 2 | .498 | .901 | 1.000 | .500 |

**Table 71: Tests of within subjects effects for mean core temperature.**

| Source | | Type III Sum of Squares | df | Mean Square | F | Sig. |
|---|---|---|---|---|---|---|
| Cond | Sphericity Assumed | .087 | 2 | .044 | .708 | .502 |
| | Greenhouse-Geisser | .087 | 1.802 | .048 | .708 | .489 |
| | Huynh-Feldt | .087 | 2.000 | .044 | .708 | .502 |
| | Lower-bound | .087 | 1.000 | .087 | .708 | .415 |
| Error(cond) | Sphericity Assumed | 1.600 | 26 | .062 | | |
| | Greenhouse-Geisser | 1.600 | 23.431 | .068 | | |
| | Huynh-Feldt | 1.600 | 26.000 | .062 | | |
| | Lower-bound | 1.600 | 13.000 | .123 | | |

# SUBJECTIVE DATA

## WHOLE THERMAL

**Table 72: Friedmans ANOVA for mean subjective whole thermal ratings during the whole test protocol.**

| | |
|---|---|
| N | 14 |
| Chi-Square | .486 |
| Df | 2 |
| Asymp. Sig. | .784 |

## CLOTHING SWEATING SENSATION

## SKILL TEST POST

**Table 73: Friedman's ANOVA statistic for skill test sweating sensation post endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 8.359 |
| Df | 2 |
| Asymp. Sig. | .015 |

a Friedman Test

**Table 74: Wilcoxon matched pairs signed ranks test for skill test sweating sensation post endurance test.**

| | SweatSkillPlaceboPost - SweatSkillControlPost | SweatSkillGCGPost – SweatSkillControlPost | SweatSkillGCGPost - SweatSkillPlaceboPost |
|---|---|---|---|
| Z | -1.134(a) | -2.521(a) | -1.998(a) |
| Asymp. Sig. (2-tailed) | .257 | .012 | .046 |

a Based on positive ranks.
b Wilcoxon Signed Ranks Test

## SPRINT TEST POST

**Table 75: Friedman's ANOVA statistic for sprint test sweating sensation post endurance test.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 14.974 |
| Df | 2 |
| Asymp. Sig. | .001 |

a Friedman Test

**Table 76: Wilcoxon matched pairs signed ranks test for sprint test sweating sensation post endurance test.**

| | SweatSprintPlaceboPost - SweatSprintControlPost | SweatSprintGCGPost – SweatSprintControlPost | SweatSprintGCGPost - SweatSprintPlaceboPost |
|---|---|---|---|
| Z | -2.309(a) | -3.071(a) | -1.897(a) |
| Asymp. Sig. (2-tailed) | .021 | .002 | .058 |

a Based on positive ranks.
b Wilcoxon Signed Ranks Test

**RECOVERY**

**Table 77: Friedman's ANOVA statistic for 20 minute recovery sweating sensation.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 8.510 |
| Df | 2 |
| Asymp. Sig. | .014 |

a Friedman Test

**Table 78: Wilcoxon matched pairs signed ranks test for 20 minute recovery sweating sensation.**

| | SweatRecoveryPlaceboAvg - SweatRecoveryControlAvg | SweatRecoveryGCGAvg - SweatRecoveryControlAvg | SweatRecoveryGCGAvg - SweatRecoveryPlaceboAvg |
|---|---|---|---|
| Z | -.983(a) | -2.014(b) | -2.606(b) |
| Asymp. Sig. (2-tailed) | .326 | .044 | .009 |

a Based on negative ranks.
b Based on positive ranks.
c Wilcoxon Signed Ranks Test

## CLOTHING COMFORT SENSATION

**Table 79: Friedmans ANOVA output for clothing comfort sensation.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 8.341 |
| Df | 2 |
| Asymp. Sig. | .015 |

**Table 80: Wilcoxon matched pairs output for clothing comfort sensation.**

| | PlaceboComfortAvg - ControlComfortAvg | GCGComfortAvg – ControlComfortAvg | GCGComfortAvg - PlaceboComfortAvg |
|---|---|---|---|
| Z | -1.492(a) | -2.511(b) | -2.509(b) |
| Asymp. Sig. (2-tailed) | .136 | .012 | .012 |

a Based on negative ranks.
b Based on positive ranks.
c Wilcoxon Signed Ranks Test

## RATE OF PERCEIVED EXERTION

**Table 81: Friedmans ANOVA for mean subjective RPE scores for the whole test protocol.**

| | |
|---|---|
| N | 14 |
| Chi-Square | 1.623 |
| Df | 2 |
| Asymp. Sig. | .444 |